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WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1924

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OFFICE OF EXPERIMENT STATIONS

E. W. ALLEN, Chief

RELATIONS WITH THE STATE EXPERIMENT STATIONS

E. W. ALLEN, W. H. BEAL, W. H. EVANS, E. R. FLINT, J. I. SCHULTE

EXPERIMENT STATION RECORD

Editor: H. L. KNIGHT

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UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

Washington, D. C. February, 1926

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By E. W. Allen, W. H. Beal, and E. R. Flint

CONTENTS

In accordance with acts of Congress giving the Department of Agriculture administrative, supervisory, and advisory functions with regard to the Federal funds for the maintenance of agricultural experiment stations in the United States and its outlying possessions, the Office of Experiment Stations to which these functions are assigned, submits herewith a report on the work and expenditures of these stations for the fiscal year ended June 30, 1924.

The reorganization of the Department of Agriculture which became effective July 1, 1923, involved the dissolution of the States Relations Service, of which the Office of Experiment Stations had been a division since July 1, 1915, and resulted in the establishment of the office as a separate unit but did not alter its relations with the experiment stations or materially modify its functions. These include (1) personal examination by representatives of the office of the work and expenditures of the stations each year, (2) review and advice regarding new projects and programs of work or revisions of old projects, (3) advice regarding questions of personnel, policy, and administration, (4) review of the literature of agricultural research throughout the world in Experiment Station Record and the preparation of other bibliographical aids to agricultural research, and (5) direct supervision of the work of the experiment stations maintained by the Department of Agriculture in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands.

FUNDS FOR STATION USE

The Federal funds for station use subject to administrative oversight by the office amounted to $1,743,600 during the year ended June 30, 1924. Of this, $1,440,000 was for the State experiment stations under the provisions of the Hatch and Adams Acts, and $205,000 for the support of the experiment stations in Alaska and the insular possessions. The total fund available for station use exclusive of

the Federal funds was $8,594,074, of which $6,115,027 was from State appropriations and $2,479,047 was from fees, sales, balances from the previous year, and miscellaneous sources, as shown in the following table:

Resources of the agricultural experiment stations from within the States for the year ended June 30, 1924

States	State appropriations	Balances	Fees	Sales	Miscellaneous	Total
Alabama	$34, 500. 00	$6, 054. 58		$16, 696. 57		$57, 251. 15
Arizona	93, 305. 06	1, 287. 88		1, 613. 54		96, 206. 48
Arkansas	50, 703. 37			15, 676. 94		66, 380. 31
California	434, 539. 92	26, 336. 43	$9, 223. 11	102, 622. 81	$16, 662. 87	589, 385. 14
Colorado	117, 540. 92	28, 951. 72		33, 332. 75		179, 825. 39
Connecticut State	88, 858. 34	226. 08	11, 000. 00		8, 048. 73	108, 133. 15
Connecticut Storrs	33, 004. 50	2, 098. 70			15, 085. 24	50, 188. 44
Delaware	17, 500. 00	2, 528. 10		11, 492. 69		31, 520. 79
Florida	91, 000. 00	20, 317. 18		9, 377. 61	8, 690. 26	129, 385. 05
Georgia	8, 000. 00	2, 396. 94		25, 786. 23		36, 183. 17
Idaho	28, 203. 31	209. 41				28, 412. 72
Illinois	368, 158. 87	27, 141. 13		61, 629. 50		456, 929. 50
Indiana	225, 081. 38	108, 103. 02	123, 443. 50	76, 312. 16	21, 072. 72	554, 012. 78
Iowa	250, 000. 00	32, 569. 13		36, 531. 95		319, 101. 08
Kansas	103, 550. 00	12, 527. 60		55, 921. 03		171, 998. 63
Kentucky	68, 000. 00	45, 243. 79	99, 158. 43	41, 144. 40	5, 000. 00	258, 546. 62
Louisiana	40, 000. 00	3, 975. 87	34, 157. 23	7, 264. 00	6, 193. 42	91, 590. 52
Maine	25. 000. 00		11, 886. 07	15, 420. 18		52, 306. 25
Maryland	86, 943. 72			16, 837. 37	11, 409. 25	115, 190. 34
Massachusetts	124, 359. 87		40, 733. 93	9, 710. 88	393. 54	175, 198. 22
Michigan	157, 963. 95			15, 626. 93		173, 590. 88
Minnesota	380, 518. 80			49, 709. 71		430, 228. 51
Mississippi	88, 196. 75	3, 936. 98		7, 394. 68		99, 528. 41
Missouri	67, 108. 55	35, 322. 76	28, 698. 16	57, 618. 41		188, 747. 88
Montana	107. 598. 62			27, 479. 06		135, 077. 68
Nebraska	123, 301. 00	22, 759. 10		40, 899. 12		186, 959. 22
Nevada	783. 65	861. 32		2, 195. 93		3, 840. 90
New Hampshire	7, 000. 00	986. 70		2, 081. 70	14, 724. 91	24, 793. 31
New Jersey	167, 500. 00		52, 029. 42	24, 324. 12		243, 853. 54
New Mexico	7, 500. 00	22, 208. 64		10, 453. 70		40, 162. 34
New York State	247, 451. 12			3, 312. 17		250, 763. 29
New York Cornell	239, 130. 65			34, 398. 47	266. 38	273, 795. 50
North Carolina	149, 161. 99	1, 497. 17		46, 030. 67		196, 689. 83
North Dakota	296, 516. 68	40, 469. 85		65, 995. 02	9, 508. 42	412, 489. 97
Ohio	597, 575. 00	13, 301. 73		55, 875. 23	673. 30	667, 425. 26
Oklahoma	12, 500. 00			6, 679. 26		19, 179. 26
Oregon	99, 500. 00	55, 337. 22			32, 161. 82	186, 999. 04
Pennsylvania	62, 225. 12			18, 636. 43		80, 861. 55
Rhode Island	3, 087. 27	2, 885. 14		7, 578. 88		13, 551. 29
South Carolina	70, 777. 60	1, 928. 71		35, 989. 24		108, 695. 55
South Dakota	35, 420. 00	5, 547. 02		9, 345. 00	3, 132. 18	53, 444. 20
Tennessee	41, 949. 52			13, 633. 69		55, 583. 21
Texas	294, 000. 00	12, 823. 23		78, 124. 43		384, 947. 66
Utah	46, 904. 73	562. 83		9, 322. 41	1, 000. 00	57, 789. 97
Vermont	5, 000. 00	586. 97	9, 741. 93	517. 80		15, 846. 70
Virginia	64, 912. 50	11, 362. 68		8, 732. 08	631. 53	85, 638. 79
Washington	107, 030. 78	17, 268. 72		51, 987. 20		176, 286. 70
West Virginia	90, 000. 00	4, 451. 46		27, 254. 55		121, 706. 01
Wisconsin	243, 663. 66			67, 944. 30	9, 740. 85	321, 348. 81
Wyoming	12, 500. 00	1, 674. 48		2, 329. 09		16, 503. 57
Total	6, 115, 027. 20	575, 740. 27	420, 071. 78	1, 318, 839. 89	164, 395. 42	8, 594, 074. 56
Federal funds						1, 440, 000. 00
Total						10, 034, 074. 56

For the first time every station received some State aid during the fiscal year 1924. There was an increase in total income of over $500,000 as compared with that of the previous year. Four stations reported no changes in their State appropriations, 29 an increase, and 17 a decrease.

Eleven stations received over $200,000 from State appropriations—Ohio, California, Minnesota, Illinois, North Dakota, Texas, Iowa, New York State station, Wisconsin, New York Cornell station, and Indiana. Nine stations receiving between $100,000 and $200,000 were New Jersey, Michigan, North Carolina, Massachusetts, Nebraska, Colorado, Montana, Washington, and Kansas. Thirteen stations receiving between $50,000 and $100,000 were Oregon, Arizona, Florida, West Virginia, Connecticut State station, Mississippi, Maryland, South Carolina, Kentucky, Missouri, Virginia, Pennsylvania, and Arkansas. Eight stations received from $25,000 to $50,-

000—Utah, Tennessee, Louisiana, South Dakota, Alabama, Connecticut Storrs station, Idaho, and Maine. Three stations—Delaware, Oklahoma, and Wyoming—received from $10,000 to $20,000. The remaining six stations—Georgia, New Mexico, New Hampshire, Rhode Island, Vermont, and Nevada—received less than $10,000 each. Further details of the station receipts and expenditures will be found on page 105.

The oversight of the Federal funds for the experiment stations pertains not only to the actual expenditures but equally as much to the maintenance of conditions favorable for the efficient use of the funds, the provision of suitable personnel, and the encouragement of an adequate grade of research effort.

TRENDS OF STATION WORK

A critical study of the progress of the research work of the experiment stations indicates certain marked and significant trends and developments. Among these are (1) sharper differentiation of research, regulatory, and service work, (2) the adoption of more specific and fundamental projects evidencing a deeper scientific insight, and (3) improvement of methods, apparatus, and technique.

About one-third of the stations, principally in the Eastern States, are still charged with regulatory or service duties of various kinds which lie outside of their primary functions as research institutions, but in recent years there has been a relative decrease in the extent and importance of station participation in such work. State departments of agriculture and similar agencies have been encouraged to take over such work and are doing so to an increasing extent. Special effort has been made by the office to obtain more exact information on this point, and with this end in mind a modification of the form of annual financial report required of the stations was put into effect during the year, which provides for a measure of differentiation of the amounts expended for research, maintenance of branch stations, surveys, conduct of farms and related commercial enterprises, and regulatory and service duties. A rough classification, based on the financial reports for the year ended June 30, 1924, shows that of the approximately $10,000,000 available for the use of the stations during that year nearly $6,500,000 was spent strictly for research and experimental purposes. Something over $500,000 was used for regulatory and public service work, and nearly $200,000 for surveys of various kinds.

Appreciation of the need of more fundamental research and of improved methods, technique, and equipment for this purpose was evident, especially in a more critical examination of the scientific competency of field and feeding experiments, the development of experimental work depending upon improved means of controlling or taking accurate account of environmental factors, and in the progress of more advanced forms of investigations in genetics, economics, and engineering.

Genetics.—The progress and importance of research in genetics as a distinct field of research was recognized by assigning to this subject a separate section in Experiment Station Record in which are brought together the more fundamental studies on the subject. Something over 100 distinct projects in genetics were reported as active at the stations during the year. Reviews of station work in genetics will be found on pages 43, 61, 67 of this report.

Economics.—The development of station research in economics has been comparatively recent, but it has made notable advance. Ten years ago there was a relatively insignificant number of station projects and workers in this field. Now the stations report over 200 active projects and more than 100 workers in economics definitely assigned to the station staffs. Despite limited resources, lack of competent investigators, and other difficulties incident to a new and distinctive research enterprise, a considerable amount of creditable and valuable work has been done, much of it through regional and national cooperation. To an increasing extent the methods of scientific research are being effectively applied to the collection and interpretation of economic facts. The opportunity for leadership by the experiment stations in this field is being more fully recognized and emphasized.

Engineering.—Interest in the development of more formal investigation in agricultural engineering is growing. The opportunity in this field is undoubtedly large, but properly trained men and facilities are limited. The office has encouraged and aided this development quite actively in various ways, and in a number of States steps were taken to give more systematic attention to such work. The number

of engineering projects reported as active in 1924 was 138. This represents a decrease in number of projects as compared with the previous year, but there was a distinct advance in the research character of the projects and an increase in the number of members of the station staffs employed in such work.

PROJECTS

New and increasing demands are being made upon the experiment stations for advice and assistance which can only be provided through research. In the attempt to meet these demands the stations are carrying a total of nearly 5,500 separate projects and employing the services of over 2,300 trained scientists.

Most of the work of the stations has now been placed on a definite project basis. The wisdom of this policy from the standpoint of administration and promotion of effective research has been fully demonstrated. It tends to encourage more specific projects and to reduce or eliminate unproductive efforts.

The actual number of projects reported as active during the year, including 181 carried on by the stations in Alaska and the insular stations, was 5,293 as compared with 5,156 the previous year. Of these 54 were purely administrative service, control, or regulatory, which, if deducted, leaves 5,239 projects devoted to research or experimentation.

The subject distribution of the projects differed little from that of last year. Field crops led with 1,722 projects, followed in descending order by horticulture 919 projects, animal production (including poultry) 638, plant diseases 450, dairy cattle and dairying 301, soils 300, fertilizers 218, rural economics 209, veterinary science 193, agricultural engineering 138, genetics 102, and foods and human nutrition 49. There was an increase during the year of 111 projects under field crops, 25 under fertilizers, 24 under dairy cattle, and 23 under rural economics.

SPREAD OF INFLUENCE OF STATION WORK

The spread of influence of station work has been rapid, not only through the agency of local substations, test farms, and the various extension services, but also through publications and publicity.

Substations.—The growth of effort to extend the benefits of station investigations by making the results more widely applicable to special problems and local conditions is reflected in an increase in substations, local experiments, and like agencies. A recent inquiry as to the number and distribution of such agencies showed that there are now in operation, in addition to the 50 State experiment stations and 4 independent stations, about 125 of what may be properly termed substations and about 180 experimental test or demonstration farms affiliated with the stations. It is evident that such extension of the station experiments meets with popular approval and legislative support, sometimes, however, to the embarrassment of administrative officers and to the neglect of or inadequate provision for other important needs of the stations.

Publications.—The regular publications of the stations have not materially increased in number and volume in recent years, remaining about 500 documents annually. The variety and extent of publication through other channels have, however, vastly increased, the net result being a distinct increase of published output, with a better adaptation of it to different classes of readers.

Since the organization of the first experiment station in 1875, the stations have issued more than 18,000 publications. A bulletin published by the Office of Experiment Stations during the year lists approximately 12,500 of the more important of these publications. This is to be followed by a series of biennial supplements, the first of which appeared in August, 1924, and listed 728 bulletins.

As a rule there has been decided improvement in appearance and subject matter of the station publications. The nature and purpose of the annual report required by the Hatch Act continues to be the subject of much discussion and diversity of practice. There appears, however, to be a tendency to reduce the report in size and make it primarily administrative. There is increasing acceptance of the view that the report is not an appropriate place for original accounts of scientific work but may properly be limited to a concise showing of the progress of the station and how it is discharging its obligations and serving the public.

To guard against waste of publications and to conserve their limited printing funds, some of the stations have abandoned mailing lists except for libraries and workers in similar

institutions, sending their publications only on individual request. Under this plan forthcoming bulletins are announced through the press and by means of post cards. Some of the stations, however, that have tried this plan have returned to the practice of maintaining regular mailing lists corrected at frequent intervals and classified according to the different lines of interest.

The differentiation in the published matter and the channels of publication is not to be taken as indicating any lack of activity in that direction or of obligation to the public. On the contrary, more attention than ever is paid to the proper publication of the station work, to publicity regarding its activities, and efforts to bring the practical results effectively before the farming people. This is believed to be in full accord with the spirit of the clause in the Hatch Act regarding publications. The only distinction is that avenues and agencies are now open for making the work of the stations known which were not in existence at the time the Hatch Act was passed, and this fact has led to a modification of practice the better to suit current conditions.

Relations with the extension service.—Naturally the cooperation of the extension service is relied upon to a large extent to give publicity and application to the work of the stations. Effective cooperation in this respect is dependent upon a recognition of mutual dependence and involves some affirmative action on both sides to maintain helpful relations. As an aid in this direction increased attention is being given to the working out of long-time State and regional programs of research and extension.

PERSONNEL

The difficulty of maintaining a competent personnel is being somewhat relieved. The annual overturn has decreased. Conditions for maintaining a more permanent research force have distinctly improved, and means of securing the advanced training required in research have increased. Graduate courses for investigators and agricultural specialists have increased, particularly in the larger institutions, and opportunities for graduate work for advanced degrees are being more freely provided. These conditions have placed a larger number of trained workers at the disposition of the stations, and the effect has been to raise the standards and the requirements for those engaged in leading lines of investigation.

Some of the more important changes in personnel during the year were as follows:

Changes in directorships.—M. J. Funchess, who had been acting director of the Alabama station, was appointed director. Dan T. Gray succeeded Bradford Knapp as director of the Arkansas station. E. D. Merrill was appointed director of the California station, succeeding C. M. Haring. R. W. Thatcher, director of the New York State station, was made also director of the New York Cornell station. B. W. Kilgore relinquished the position of director of extension and became dean of the school of agriculture at the North Carolina State College, in addition to the directorship of the station. C. T. Dowell resumed the directorship of the Oklahoma station, succeeding M. A. Beeson. C. A. Mooers, vice director of the Tennessee station, was made director. William Peterson, director of the Utah station, was made also director of extension, succeeding R. J. Evans.

Other changes.—W. E. Hinds, chief of the department of entomology, and F. L. Thomas, associate entomologist of the Alabama station, resigned. J. M. Robinson was made acting head of the department, and H. G. Good was appointed assistant entomologist.

A. E. Vinson, chief of the department of chemistry of the Arizona station, resigned. H. Embleton succeeded R. B. Thompson in charge of the poultry department.

W. A. Lippincott was appointed in charge of the poultry work at the California station. Appointments in the grade of associates at this station included D. E. Davis in veterinary science, J. H. Irish in fruit products investigations, and H. J. Smith in entomology. H. E. Van Norman of the dairy department resigned. E. J. Wickson, former director and horticulturist, died July 21, 1923.

A. K. Peitersen, botanist of the Colorado station, died February 23, 1924.

C. M. Slagg, in charge of the tobacco substation in Connecticut, resigned. I. G. Davis was appointed agricultural economist at the Storrs station.

G. H. Blackmon was appointed pecan specialist and E. L. Ayers agriculturist at the Florida station.

D. G. Sullins, in charge of the animal husbandry work at the Georgia

station, resigned and was succeeded by F. R. Edwards.

Changes at the Ilinois station included the appointment of B. Koehler in charge of crop pathology in the agronomy department, the resignation of B. S. Pickett, chief pomologist at the station, and the appointment of V. W. Kelley as associate in pomology, and of E. P. Lewis as associate in olericulture.

The more important changes at the Indiana station were as follows: A. A. Hansen was appointed associate in botany, and D. B. Clark resigned as associate in veterinary science.

At the Iowa station B. S. Pickett was appointed chief in horticulture, and P. H. Elwood, jr., was made chief in landscape architecture. H. W. Johnson resigned as assistant chief in the soils section and was succeeded by H. J. Harper. Paul Emerson resigned as assistant chief in soil bacteriology and was succeeded by L. W. Erdman. F. A. Fenton, associate and assistant chief in entomology, resigned.

Appointments at the Kansas station included A. H. Helder in charge of landscape gardening to succeed W. S. Wiedorn, resigned, H. E. Reed in charge of sheep husbandry, L. F. Payne to succeed W. A. Lippincott in charge of the poultry department, D. C. Warren in charge of poultry genetics, and C. O. Swanson head of the milling department.

T. H. Jones resigned as entomologist of the Louisiana station and was succeeded by W. E. Hinds. R. Dodson was appointed forage crop specialist.

H. F. Tompson, in charge of the Massachusetts market garden field station, resigned.

LeRoy Cady, associate horticulturist of the Minnesota station, died September 11, 1923.

R. F. Howard, chairman of the department of horticulture at the Nebraska station, resigned and was succeeded by C. C. Wiggans.

J. J. Black was appointed poultry pathologist and W. H. Dumont oyster research specialist at the New Jersey stations.

J. M. Sherman was appointed head of the dairy industry department of the New York Cornell station.

Stanley Combs resigned as dairy experimentalist at the North Carolina station and was succeeded by V. M. Williams. J. P. Pillsbury, head of the department of horticulture, was transferred to the college faculty and was succeeded on the station staff by C. D. Matthews. B. F. Brown, chief of marketing, was transferred to the college staff.

Glen McIlroy, of the poultry department of the North Dakota station, resigned and was succeeded by J. R. Redditt. L. R. Holland, in charge of dairy manufactures, resigned.

G. W. Cochran was made head of the department of horticulture of the Oklahoma station and F. M. Rolfs plant pathologist. R. B. Thompson was put in charge of the poultry work.

D. C. Mote was made entomologist of the Oregon station on the death of A. L. Lovett, which occurred in April, 1924. B. B. Fulton resigned as associate entomologist and E. W. Bressman was appointed associate agronomist.

A. K. Anderson was made associate in agricultural chemistry at the Pennsylvania station and W. T. Tapley succeeded W. C. Pelton in vegetable gardening. I. D. Wilson, veterinarian, resigned.

F. T. McLean succeeded H. B. Hall in the department of botany at the Rhode Island station, and F. R. Pember, of the department of chemistry, resigned.

N. E. Winters, in charge of the boll weevil control work of the South Carolina station, resigned and was succeeded by G. M. Armstrong. C. O. Eddy was appointed associate in the department of entomology.

R. E. Hunt, head of the department of animal husbandry of the Virginia station, was transferred to college work.

At the Washington station S. C. Vandecaveye succeeded P. W. Allen as bacteriologist.

ADMINISTRATION

Progress in the development and improvement of methods of administration of research and in coordination of effort are recorded in many cases. There is evidence of a growing appreciation of the need of closer administrative and staff contacts, and of the value of committee work and conferences. The increasing need for inspiring leadership to promote cooperation and teamwork accentuates the importance of close administrative attention to station affairs and argues strongly for the independent station director who can give his attention exclusively to station affairs. The present situation is as follows:

In 20 States there are separate station directors—Colorado, Connecticut,

Georgia, Maine, Maryland, Massachusetts, Mississippi, Nevada, New Mexico, New York, North Dakota, Ohio, Oregon, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Virginia, and West Virginia. The dean of agriculture is likewise director of the station in 18 States—Alabama, Arizona, California, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Montana, Nebraska, New Jersey, North Carolina, Oklahoma, Pennsylvania, Vermont, Washington, and Wyoming. In 3 States—Indiana, New Hampshire, and Utah—the offices of director of the station and director of extension are combined. In 7 States—Arkansas, Delaware, Florida, Idaho, Illinois, Kentucky, and Wisconsin—the director of the station is also dean of agriculture and director of extension.

The total volume of station work of the best type was never larger or more promptly put to practical use. Agricultural research has, however, reached a difficult and critical stage in its development which may lead to a decrease in volume of striking and quickly applicable results. The simple problems have in large measure been solved or the means of solution worked out. Discoveries likely to revolutionize practice are less frequent. More profound and complex problems, requiring new technique and methods and deeper and clearer insight into the relations of cause and effect, have been uncovered. Routine applications of conventional methods will no longer suffice. Whether this stage shall mark the beginning of an era of diminishing returns in agricultural research, as has been suggested, will depend upon the attitude of those engaged in the work of both administration and investigation and the use they make of their opportunities and means. As public servants, the station administrators will be depended upon to make the most of the available resources and facilities and to guard against ineffective and unprofitable effort. On the other hand, the individual investigator will be expected to assure himself that his research is growing in effectiveness and not merely increasing in volume without improving in kind.

STATE LEGISLATION AFFECTING THE STATIONS

There was only a limited amount of special State legislation affecting the stations during the year. The following are some of the features of such legislation:

The Kentucky Legislature provided for the establishment of two substations, each on land donated for the purpose. The first was located near Quicksand, Breathitt County, the other at Princeton, Caldwell County. An annual appropriation of $25,000 was provided for the former and $20,000 for the latter.

The New Jersey Legislature provided for the establishment of a poultry disease laboratory at Vineland and appropriated $5,000 annually for its maintenance.

The Virginia Legislature passed a comprehensive act which provided among other things for an agricultural survey of the State under the direction and supervision of the experiment station with the object of developing the agricultural interests and resources of the State.

The Oklahoma Legislature placed an inspection tax on commercial fertilizers sold in the State, the major portion of the funds so derived going to the station. The receipts from this source amounted to between $900 and $1,000 the first year and are expected to increase.

Under a State electrical district law enacted by the Arizona Legislature, two districts were organized and developed with the cooperation of the station.

ADDITIONS TO BUILDINGS AND EQUIPMENT

A large part of the additions to the buildings and equipment of the stations during the year were of the ordinary kind. Many of them, however, were of a kind that evidenced a growing recognition of the need of special provision for investigation which requires more exact control or measurement of environmental conditions and factors—temperature, moisture, light, and air—in the multitude of problems of research in which such control or measurement is a necessity. The tendency is more and more to make provision for this purpose in the original construction of laboratory buildings and plant houses rather than by means of special independent pieces of apparatus or supplementary equipment.

A notable increase in special structures for small experimental animals is recorded—a necessary outgrowth of the great extension in recent years of the use of such animals for research,

especially in nutrition and animal diseases.

Some of the more important additions to station buildings and equipment during the year were as follows:

At the Arkansas station a greenhouse was built, a water system installed at the station farm, and 100 acres of land adjoining the farm was bought for $16,000. Cottages were built on the farm, and considerable improvements were made in draining, fencing, etc.

The California Legislature appropriated $100,000 for the purchase of land and construction of greenhouses at Berkeley contingent upon $50,000 being raised locally. The latter was secured by private subscription, and about 18 acres of land was purchased near the university campus. A new head house was built at the Citrus station at Riverside. At Davis a new field laboratory for truck crops was constructed and equipped, a wing was added to the veterinary building, and a shop building was constructed for the engineering department. Laboratory space was provided for poultry husbandry, and an irrigation system for 20 acres was installed.

A new seed house was built at the Fort Lewis substation in Colorado, and a special appropriation of $4,000 was used for barns and other improvements at the Cheyenne Wells substation. At the Akron substation 154 acres of land was added by purchase.

At the Connecticut Storrs station the construction of a wing to the dairy barn was begun, and a maternity shed was built for abortion experiments. A small building was erected and equipped for indoor chick feeding experiments.

The Florida station reports the addition of small greenhouses and barns at Everglades substation.

At the Georgia station improvements were made in the chemical laboratory, and a sweet potato storage house and a concrete root cellar were built to replace one destroyed by fire.

A part of a new poultry plant was completed at the Illinois station, and construction of a new horse barn, a swine barn, and a central poultry house was begun. Plans for a new dairy manufactures building and a new dairy barn were completed during the year. A respiration calorimeter for animals of any size was built.

At the Indiana station the construction of a unit of the greenhouse for the horticultural and entomological work was begun, and a new building for small animals used in nutrition investigations was provided. A new livestock farm of 442 acres was secured about 3 miles from the station, which is equipped for housing 40 brood sows but can be used for cattle and sheep. The board of trustees accepted a 40-acre experiment field in Marshall County.

At the Iowa station 80 acres was added to the dairy farm, 133 acres for horticultural work, and 10 acres for bee investigations. The poultry department added three permanent laying houses and six movable rearing houses.

In Louisiana the agricultural building on the new site of the university at Baton Rouge approached completion, and a dairy barn and other farm buildings were occupied. Steps were taken to transfer the sugar house work at Audubon Park to the new site at Baton Rouge. A new barn was constructed at the Fruit and Truck substation at Hammond.

Construction was started at the Michigan station on a new horticultural building to cost $250,000, with $75,000 for equipment, and greenhouses to cost $39,000.

A new dairy barn costing $220,000 was completed at the Minnesota station. A refrigerating machine for investigations requiring temperature control was installed.

The new agricultural building at the Missouri station was equipped and occupied.

At the Nebraska station 64 acres was purchased for additional experimental work with beef and dairy cattle.

An oyster research laboratory was established by the New Jersey stations at Bivalve, N. J. A dairy and animal husbandry building was built and equipped at a cost of $200,000, and buildings to house the livestock of the station and college were built at a cost of about $50,000. Two additional farms were purchased, totaling 150 acres, for the horticulture and farm crops departments of the college and station. Considerable additions were made to the station dairy herd.

At the New Mexico station 11 acres of land was added to the horticultural farm, and a number of smaller buildings were constructed for the poultry department.

The new dairy industry building of the New York Cornell station, costing $568,000, was completed and occupied during the year. Plans for a new plant industry building and a new library were completed.

The new agricultural building, Ricks Hall, at the North Carolina station, costing $200,000, was completed and occupied largely by the station. A swine experiment farm of 72 acres near Raleigh was purchased. A new swine plant and central feeding house with other improvements were added to the Black Land substation, near Wenona, and new office buildings, laboratory, and insectary at the Coastal Plain substation, near Willard. A new calf barn, spring house, insectary, and a five-room cottage were built at the Mountain substation, near Swannanoa.

Improvements at the North Dakota station included an addition to the dairy barn, a poultry brooder house, a greenhouse for the agronomy department, and apparatus for the investigation of macaroni wheat.

The new laboratory and office building of the Ohio station to be known as Thorne Hall neared completion. It is to be used for the departments of soils, chemistry, botany, and entomology. The appropriation for this building was $75,000. A forest and park of 5,986 acres was purchased.

At the Oklahoma station a new animal husbandry building with a stock judging pavilion to cost $125,000 was nearly completed. This is to be used partly for station work. A cattle feeding shed was provided for. The dairy building was improved, and the new dairy barn, costing $48,000, was completed and occupied. A sweet potato storage house and a concrete root cellar were built.

At the Oregon station two modern laying houses each with a capacity of 300 hens were erected. Six additional acres were secured for the substation at Talent.

The construction of a beef cattle feeding barn with silo was begun at the South Carolina station. An office building for boll weevil control work was built at the Pee Dee substation.

At the Utah station a new greenhouse was completed and equipped, and the construction of a plant for egg-laying contests was begun. A farm of 86 acres adjoining the Greenville farm was acquired, and a 30-cow dairy barn was built to be devoted exclusively to dairy work.

At the Washington station an additional laying house unit was added to the poultry plant.

The new dairy barn at the West Virginia station was completed during the year. At the Reymann Memorial Experiment Farm a creamery was built and equipped with an ice plant.

The Wyoming station built a shed for horses with paddocks and feed racks at Laramie, added a poultry house at the substation at Torrington, and enlarged the dairy barn at the substation at Lyman.

INSULAR EXPERIMENT STATIONS

The work and expenditures of the experiment stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands were supervised as heretofore by the Office of Experiment Stations under direct charge of Walter H. Evans, Chief of Insular Stations.

These stations were supported by appropriations made directly to the United States Department of Agriculture, as follows: Alaska, $70,000; Hawaii, $50,000; Porto Rico, $50,000; Guam, $15,000; and the Virgin Islands, $20,000. A statement of income and additions to equipment of the stations is given on page 108 of this report. The results of the work of the stations are published in their reports, bulletins, and circulars.

The guiding policy in the work of these stations has been to develop a type of agriculture suited to the varied conditions of Alaska, to diversify the agriculture of Hawaii, Porto Rico, and the Virgin Islands, and to restore that of Guam to its former importance.

The agriculture of Alaska is being developed to supply the growing needs of the Territory. With the varied conditions of soil, climate, and length of season, it is necessary to make investigations along many lines. These include, among others, much adaptation work, which is beginning to show results, and development of selected and hybrid grains, which are proving superior to introduced varieties. In Hawaii the banana and pineapple industries particularly show the influence of the station's work, and the pigeon pea introduced by the station is greatly increasing the forage resources of the islands, as well as improving the fertility of the soil. The influence of work begun by the Porto Rico station to eliminate the cattle tick has been widely extended, with the result that there are now more than 200 dipping vats in use in the island. Many plantations have been freed of ticks and cattle are being rapidly improved. Dairying promoted by the station work is becoming an important industry of the island.

Much of the time and effort of the Guam station during the year was devoted to repairing damage done to the station property by a typhoon and to

attempts to check the spread of the coconut scale, which threatens the leading industry of the island.

The Virgin Islands station has shown the possibility of growing vegetables in considerable variety and quantity if attention is paid to favorable times of planting and proper methods of culture. Larger supplies of local-grown vegetables of better quality are now to be found in the markets.

SOME RESULTS OF STATION WORK

The following are examples of recent contributions in the various fields of station work:

SOILS AND FERTILIZERS

The stations report 300 active projects relating directly to soils and more than 200 dealing with fertilizers. These cover practically every feature of the subject of soil fertility and maintenance, including soil surveys, fertilizer requirements, and correction of infertile conditions. The work is national, regional, State, and local in scope, dealing with both generalized and specialized conditions.

Much of the work with soils has been designed simply to secure empirical results, but more and more it is being directed toward fundamental inquiry into the causes of the observed phenomena and coordinated toward a definite end. For example, in the study of soil acidity which is a widespread condition and of alkalinity which affects in the aggregate a large area of land but is more localized, investigation is going beyond mere tests of the intensity and correctives of such conditions and is undertaking to determine the causes of the conditions and the response of different crop plants to them.

A significant trend of recent work on soils has been in the direction of a somewhat systematic determination of the optimum conditions of soil acidity or alkalinity for different kinds of plants and of the simplest and most efficient and economical means of maintaining these conditions permanently. The Wisconsin station has been especially active in such work, but several other stations are making investigations contributing toward the same end.

Acidity.—The specific causes of soil acidity have been the subject of much investigation by the stations. Investigations by the California station indicate that acid soils are simply normal soils which have lost more or less of their calcium by solution in carbonated water and its removal by leaching or absorption by plants. The Rhode Island station, which attributes the growth-inhibiting action of certain so-called acid soils to soluble aluminum compounds, finds that both lime and soluble phosphates are correctives of the trouble, a combination of the two being especially effective.

Alkalinity.—The movement of soluble salts in soils and their removal by leaching have been studied by a number of stations. It has been observed that attempts to remove alkali by leaching generally develop a condition of impermeability which arrests the process and leaves the soil in bad physical condition for tillage.

Wide variations in the rate of movement of different soluble salts in the soil are observed. The New Mexico station found that nitrates moved more rapidly than chlorides and sulphates in either capillary or drainage water. This station also found that practically no phosphoric acid was lost in drainage water. Approximately 80 per cent of the water-soluble potash was leached out and 50 per cent of the nitrogen was so removed.

Liming.—Station investigations relating to lime as a corrective of acidity and for improving the physical condition of soils have been numerous. To an increasing extent, however, attention is turning to the relation of lime to the solubility and movement of other constituents of the soil. The Tennessee station found that the addition of calcium compounds increased the outgo of calcium salts from the surface soil and subsoil, although the subsoil absorbed some of the calcium salts leached from the surface soil. The addition of magnesium compounds decreased the outgo of lime salts from the surface soil. Applications of lime and magnesia increased the outgo of sulphur from the soil and decreased the outgo of potash.

Much attention has been given to study of the relative efficiency of lime compounds of different degrees of fineness. The Pennsylvania station found that a large part of the coarse particles of limestone applied to soil accumulated in the subsurface without disintegration. The Illinois station found that limestone coarser than 0.05 inch had very little effect during the first two years, and that coarser than 0.10 inch was comparatively ineffective for three or more years.

Nitrogen and nitrates.—The Nebraska station found a very low rate of nitrate accumulation in soils which had been depleted of their organic matter. The California station found that nitrate accumulation is low under grain, alfalfa, or clover, and high under grapes and cultivated crops. The latter station also found that sulphur depresses nitrate formation in the soil. The Georgia station reports that it prevents loss of nitrogen from compost heaps, aids ammonification, prevents loss of free nitrogen, and apparently prevents nitrification.

Manure.—The Utah station found that manure increased the loss of lime from soils, but this effect decreased as the irrigation water applied was increased. The calcium-magnesium ratio was widened by both manure and irrigation water. In a highly calcareous soil to which 5 tons of manure had been applied annually for 12 years the Utah station found that the soil had stored at the end of that period 17.7 per cent of the carbon and the organic matter which had been applied, and where 15 tons of manure had been applied annually 71.4 per cent of carbon was retained. The application of manure tended to widen the carbon-nitrogen ratio, whereas irrigation water narrowed it.

The increasing scarcity of manure has directed attention to possible substitutes for it. Some of the stations are studying the possibility of converting straw and other waste materials into a manure substitute. The Washington station found that straw humification is speeded up by adding sodium nitrate or ammonium sulphate and calcium carbonate.

PLANT PHYSIOLOGY

The study of questions of plant improvement and production has led station investigators far into the field of plant physiology, and the number of noteworthy achievements in this line is rapidly increasing. Some results of recent investigations of this kind are as follows:

Formation of sugars.—Studying the formation of sugars in the leaves of corn and sorghum collected at two-hour intervals, the Kansas station found that the total sugars began to increase between 4 and 6 a. m., reaching a maximum at from 12 m. to 5 p. m., and decreased gradually from that time until daylight the following morning. The nonreducing sugars were in excess of the reducing sugars. The former increased markedly during the day and decreased during the night, while the latter usually showed very little increase, and the amount present at different periods of the day was very irregular. No significant differences were observed between corn and the sorghums in regard to the relationship between reducing and nonreducing sugars in the leaves.

Transfer of nutrients.—The effect of fertilizers, especially nitrate of soda, applied to the soil on one side of a fruit tree was found by the Maryland station to be confined to that side. Apparently there is very little cross transfer of nutrients in certain plants, and the foods elaborated on one side of the plant are used and stored mainly on that side.

Oxidase activity.—A positive correlation of increased oxidase activity with decreasing dormancy in the latter part of the spring was noted by the Minnesota station. A number of water plants grown in gas-tight tanks to which carbon dioxide was supplied under artificial light bloomed in January and February, while under ordinary conditions they would bloom in July.

Temperature effects.—The maximum temperature at which potatoes produced tubers was shown by the Minnesota station to be between 20° and 23° C. Failure to produce tubers at the higher temperature is attributed to an increase in the rate of respiration, consuming the carbohydrates that at the lower temperatures are stored in the tubers.

Water requirements.—The water requirements of corn and sorghum were shown by the Kansas station to vary greatly with varieties, especially in sorghums. No relationship was found, however, between the water requirements of a plant and its ability to withstand drought.

Light effects.—Corn, wheat, and potatoes under constant light, temperature, and humidity showed a uniform rate of growth with no inherent daily periodicity, in experiments at the Minnesota station. There was a relatively constant quantity of starch and other carbohydrates in the leaf. Tobacco plants subjected to a light intensity of about 200 candles (one-twentieth of average daylight) during the day were especially subject to attacks of parasites, and apparently did not accumulate sufficient plant food during the day to maintain their growth. Plants grown under artificial illumination at night produced more growth of tops and stronger

roots than those grown in daylight alone and were less subject to disease. Artificial light seemed to reduce the susceptibility of seedlings to damping off.

Mineral nutrients.—Marked effect on absorption of mineral nutrients by barley was observed in experiments at the California station in which sodium chloride and sodium sulphate were added to the culture solution, the tendency being to decrease the absorption of calcium, magnesium, and potassium. Rapid and extreme changes in the reaction of the sap expressed from the roots were caused by the addition of sodium bicarbonate to the culture solution. Young orange trees showed serious injury when grown in culture solutions to which no calcium was supplied. Trees in cultures to which no potash salts were added made a fair growth and did not show as much injury as those lacking calcium. There was a tendency of the chlorophyll to fade out, and the sap of the leaves was slightly more acid than in case of those receiving potassium. Leaves of trees to which no calcium salts were applied were rich in potassium and, conversely, those receiving no potassium were high in calcium. Where calcium salts were withheld the trunks and roots were the last to be depleted of that ion, and where potassium was withheld the roots and rootlets were last to be depleted of this ion. Experiments indicate that stimulation of the growth and respiration of wheat may be induced by suitable concentrations of sodium chloride under certain climatic conditions.

Iron, manganese, copper, and zinc were found by the Kentucky station to occur in greater concentration in the pericarp and germ of wheat, corn, soy beans, and oats than in the endosperm, so that these substances are removed for the most part in the modern process of milling, with a probable lowering of the nutritive value of the flour produced. This station reported further confirmation of its previous conclusions that manganese is one of the elements necessary in minute quantity to the normal growth of green plants, and that other metallic elements or combinations may function in the same way. Experiments with wheat, oats, and tomatoes suggested that copper and zinc may perform an essential function in the fructification and development of the seeds of plants.

FIELD CROPS

Recent work of the stations on field crops has dealt largely with development of varieties of improved quality and increased disease resistance. This feature of the work is reviewed in the special article beginning on page 43 of this report. Progress is also reported in the study of cultural methods and rotations and various factors which affect the economic value of crops.

Factors affecting composition.—The Utah station found that the content of nitrogen in wheat, oats, and barley decreased and the mineral constituents increased with the amount of irrigation water used. The Kansas station finds that weather is the strongest factor influencing the protein content of wheat, but that crop rotation may have an important influence in this respect. Early preparation of land for wheat increased not only the yield but also the protein content. From studies reported by the North Dakota station, it appears that the most influential climatic factor affecting the quality of wheat is the mean daily temperature of the growing season. A cool season tends to produce a heavy plump grain with a low protein content, while high temperatures and hot winds produce shriveled berries of high protein content. It was observed that use of leguminous crops in the rotation tended to increase the protein content of wheat.

Chromosome numbers.—The Maine station found a high degree of correlation between chromosome numbers and adaptability and economic value of wheat species. Species with 7 chromosomes are of no economic value and are found only in hot tropical regions. Those with 14 chromosomes are of some economic value but not adapted to the making of light bread. They are mostly spring wheats and not suitable for cold climates. Species with 21 chromosomes are of greatest economic value and include the only varieties suitable for making white bread. The possible value of increasing the chromosomes by artificial means and thus improving the quality of wheat is suggested.

Baking quality of wheat.—Studies at the Nebraska station show that high protein frequently fails to correlate with high baking quality, that the wide variation in the baking quality of the wheats of the State is due to differ-

ence in gluten quality or to a factor as yet unknown, that there is no correlation between commercial grades and quality, that the higher protein winter wheats from the more arid regions of western Nebraska are generally of poorer baking quality than the winter wheats of eastern and southern Nebraska, and that quality is improved by the use of legumes in crop rotation systems. It was also found that although proteins from different wheats may differ slightly in chemical configuration, these differences are not a determining factor in flour strength.

Soft corn.—The soft corn problem has received the attention of several of the stations, particularly in the Corn Belt. The Iowa station found that soft corn, fairly mature and only slightly molded, made silage that was palatable, clean, and bright, and of good aroma. The dry matter recovery was higher in dried than in the ensiled corn, but the recovery of protein was highest in the better grades of silage. The cost of ensiling was approximately 13 cents per 100 pounds, and of drying 21 cents. In experiments at the Ohio station it was found that the grain portion of ensiled corn lost a considerable part of its protein, in some cases practically half, the loss being greater when the kernels were broken.

Ensiling versus field curing of corn.—The Missouri station reports comparative tests which showed smaller losses in dry matter but considerably larger losses of protein in ensiling than in field curing.

Disease-free seed potatoes.—Much of the work of the stations on potatoes has centered around the question of means of securing disease-free seed. Preliminary studies at the Oregon station indicate the need of widespread adoption of the seed plat plan for virus disease control as the only means now known by which growers can approach a reasonable degree of success in eliminating this class of troubles.

Inoculation of legumes.—A number of stations are engaged in studies on the effect of inoculation on various legumes. The Arizona station reports that inoculation hastened the maturity of alfalfa from five to seven days and materially increased the yield of this and other legumes. It was noted that inoculation increased the nitrogen content in a number of cases. For example, it increased the nitrogen content of alfalfa from 1 to 9 pounds per ton, that of cowpeas 16 pounds, and of soy beans 2.6 pounds. The Illinois station has found no legume bacteria which can be cross-inoculated on the soy bean.

Succession and rotation of crops.—The effect of one crop upon another in a rotation is being studied by a number of the stations with positive results of much interest. Averaging 10 years' experiments, the Illinois station finds that continuous corn has yielded 24.8 bushels per acre; grown in a 2-year rotation with oats, 35.2 bushels; and in a 3-year rotation of corn, oats, and clover, 43.1 bushels. On similar plats treated with manure, lime, and phosphates, continuous corn averaged 43.8 bushels per acre; a 2-year rotation, 68.7 bushels; and the 3-year rotation, 58.9 bushels. At the Kentucky station the yield of wheat after corn was 9.3 bushels per acre; after tobacco, 16.9 bushels; after soy beans, 10.6 bushels; after oats, 13.2 bushels; and after turning under a crop of cowpeas, 32.2 bushels.

At the Minnesota station wheat following soy beans, red clover and sweet clover, field peas, and corn yielded over 11.7 bushels per acre, while following oats the yield was 4.06 bushels. Flax following corn gave the best yields. The lowest yields were those following timothy and grain crops. Buckwheat lodged badly following the cultivated and leguminous crops, this being particularly bad following potatoes and corn, with low yields. The best yields were obtained following wheat, oats, barley, rye, and buckwheat. Soy beans yielded about equally well following all crops, when they were well inoculated. Following the leguminous crops they lodged considerably and were uneven in maturing. Yields of shelled corn per acre were highest following the legume crops, with the exception of soy beans. Sorghums, soy beans, and timothy following corn resulted in less than 50 per cent of the yields following the other leguminous crops or the grains.

Longevity of weed seeds.—In studies at the Iowa station with seeds buried under out-of-door conditions, those that have survived for 12 years were velvet leaf, jimson weed, horse nettle, catnip, and honey locust. Five-finger lived 10 years, curled dock 9 years, tumbling pigweed 8 years, burdock 7 years, lamb's quarter 6 years, and Dalea, field thistle, and evening primrose 5 years.

HORTICULTURE

Horticulture is second only to field crops in the number of projects under

investigation by the stations. Some representative contributions of the stations in this field during the year were as follows:

Fruitfulness.—The determining causes and possible control of fruitfulness are receiving much attention by the stations. Studying the question of fruit spurs in relation to fruitfulness, the Iowa station observed that fruit spurs make their greatest growth in a few days at the time of blossoming. The length of this growth, in a measure, regulates the quantity and regularity of fruit production. If the growth is uniform in length, especially if it is short, off-year production is indicated, whereas growths of variable lengths indicate regular annual production. Length of the growth can be controlled by pruning, by the use of fertilizers, or by a combination of the two.

The rate of growth of grafted buds when they begin to grow in the spring, which may vary considerably, was found by the Maine station to depend upon inherent properties of the individual buds and not to differences in compatibility with the seedling root. Buds taken from the most productive trees in an orchard and worked on Northern Spy rooted cuttings after 12 years' growth in the orchard at the New York State station showed no advantage over those from the least productive trees. Standard varieties on their own roots proved preferable to the same varieties top-worked on young Northern Spy trees.

In experiments at the New Hampshire station 12-year-old Oldenburg (*Duchess*) apple trees shaded for two seasons showed almost no fruit bud formation, while unshaded trees showed about 65 per cent fruit bud formation. Ringing was found to increase fruit bud formation. It is concluded that the effects of shading in decreasing and of ringing in increasing fruit bud formation are in accord with the theory of the relation of carbohydrates and nitrogen to growth and reproduction. The Indiana station found that cutting back young trees delayed the formation of fruit spurs and fruit buds and thus delayed fruitfulness. Unpruned or lightly pruned trees produced more fruit than trees which had received heavier pruning. In experiments at the Kentucky station heavy pruning of apples delayed bearing, was unfavorable to the set of fruit, and greatly increased the amount of pruning required later because of the thick tops resulting from the cutting back.

Studies at the Maryland station on the relation of pruning to the root development of the grape show that, contrary to the usual idea, heavy pruning does not promote root development, the best development being found with the lighter pruned vines. Fruit buds in the middle of the cane gave higher yields than those on other parts. In a comparison of cane and spur pruning at the Nebraska station, there were a higher percentage of productive buds, a slightly larger number of clusters per productive bud, and slightly larger clusters in the cane-pruned plants.

Fertilizing orchards.—The question of the actual value of fertilizers for orchard fruits under ordinary conditions is being studied by a number of stations. The New York State station, summarizing the results of a long series of tests, concludes that in apple orchards on the better soil types of that State, with clean cultivation, the use of commercial fertilizers is not justified from an investment standpoint, although with some other fruits, especially cherries, the application of available nitrogen may be beneficial. Orchards in sod or in poor soils or those not properly cared for will respond to fertilization.

Fifteen years' tests at the Pennsylvania station have shown that the apple orchards of that State may be kept permanently and successfully in sod, provided the resulting nitrogen deficiency is made up by early spring applications of nitrogenous fertilizers and a heavy growth of grass is obtained and used as a mulch. Applications of nitrate of soda to orchards in sod increased the growth, vigor, and yields. Applying the nitrate before the blooming season, namely, about the time the leaf buds break, has given larger yields than applications made immediately after the blooming season. In experiments at the Delaware station fertilizers delayed ripening and coloring but increased the size of apples. Trees receiving only nitrate produced smaller fruit than those supplied with a better balanced fertilizer. Trees receiving nitrogen were the first to shed their leaves in the fall, an undesirable feature from the standpoint of fruit bud formation.

In fertilizer experiments with peaches at the West Virginia station nitrogen was the only element that increased vegetative growth and yield of fruit sufficiently to be of any eco-

nomic importance. Application of nitrate of soda or stable manure delayed the maturity of the fruit from eight to ten days or more, depending on the season and the quantities applied. Fertilizers had no marked effect in increasing the size of the fruit. Nitrate of soda and manure increased the yield but not the percentage of fancy or extra fancy fruit. None of the fertilizers had a marked effect on the percentage of fruit buds formed. Trees receiving nitrate produced larger leaves and denser foliage than those not so treated, but the fruit was poor in color, largely as a result of shading.

Effect of place of origin of apples.—The New York State station reports that Baldwin apple trees from 40 different localities in the United States now in bearing at the station produce fruits similar in size, color, season, and quality, showing that strains have not originated necessarily because of difference in environment.

Sex in strawberries.—Pollination experiments at the Vermont station indicate that the sexual nature of the strawberry is hereditary, since in both open and self-pollination trials with perfect varieties the progeny were nearly all perfect, whereas in the open pollination of imperfect varieties only about half of the progeny were perfect. Observations on the breeding of perfect and imperfect varieties show that it is possible, in some cases, by careful selection, to introduce the missing sex into an imperfect variety without materially changing its characteristics. Sterility in the strawberry, as now understood, appears to be largely a matter of sex inheritance.

Fruit products.—The important question of the utilization of surplus fruit and by-products is receiving much attention by several stations, notably those of California, Illinois, and others. The Delaware station has recently reported some especially noteworthy investigations on the effect of varying proportions of sugar on the texture, flavor, and yield of fruit jellies. There appears to be no specific amount of sugar that must be added to insure the successful formation of a jelly, but, other conditions being equal, a weak jelly results from too much and a tough jelly from too little sugar. Although the proportion of sugar added may vary over a wide range, the percentage of sugar that exists in the finished jelly is fairly constant at about 69 per cent. The function of the sugar may be that of a dehydrating agent, while the acid is believed to control the precipitation of the pectin in jelly form. The formation of fruit jellies could not be correlated with the total acidity, but there was a direct relation between jelly formation and active acidity or H-ion concentration, the minimum at which this occurred being pH 3.46. Jelly formation occurred irrespective of the quantity of pectin present, once the minimum H-ion concentration was attained, but the quantity of pectin had to equal the minimum amount that was necessary to produce a jelly. With pectin, sugar, and water maintained constant, the character of the jelly was determined by the H-ion concentration, the jelly being stiffer as this increased.

PLANT DISEASES

The work of the stations on plant diseases is extensive and varied. Recently special emphasis has been placed upon immunity and the development of resistant varieties and strains of plants, varying virulence of different strains of the diseases, and conditions favoring the spread or control of diseases. Such widespread and destructive diseases as the so-called degeneration diseases of potatoes, and rusts, smuts, and rots of cereals have claimed a large share of attention, and substantial progress in their control is recorded.

Potato diseases.—Recent work of stations on mosaic and other degeneration diseases of potatoes has emphasized especially the varying manifestations of these diseases under different environmental conditions and with different varieties. The Nebraska station has observed that temperatures above 70° F. tend to decrease the number and severity of symptoms of mosaic and that under field conditions mosaic is more severe with early plantings, while spindle tuber is more in evidence in late plantings. Short periods of four to eight days of high temperature and increased sunlight were found sufficient to eliminate the leaf symptoms of mild mosaic and to decrease those of the more severe type. The Utah station found the symptoms to vary in different varieties and observed two distinct forms of the disease, one showing definite mottling with little or no dwarfing and one with prominent mottling, crinkling, and dwarfing.

Earlier work of the Maine station showed aphids to be active carriers of mosaic. Later observations indi-

cate other transmitting agent in addition to aphids.

In extensive studies of diseases attacking the potato tuber internally, the North Dakota station found that the blackleg bacillus, as well as the Fusarium wilt fungus, is a very common cause of stem end discoloration and that both of these organisms may be present in the same tuber. A large number of discolored tubers was found from which no organism could be isolated. Removal of the stem end of seed tubers is urged as a control measure.

Cereal diseases.—The work of the stations on cereal diseases is very extensive, a large part of it being done in cooperation between different stations and with the Office of Cereal Investigations of the United States Department of Agriculture. There appear to be several types of resistance to rust (*Puccinia graminis*) in wheat according to the Minnesota station, which also reports that fertilization with phosphorus and potash appears to enable the plants to withstand attacks of the disease.

The Indiana station has reported the alternate hosts of various cereal rusts and has shown that the leaf rusts of wheat, rye, barley, and corn are distinct from similar rusts on wild grasses, each apparently being restricted to the one cereal. The station considers the development of resistant varieties to be the most promising method of control. Of the wheats, the durums and emmers, as a group, are outstanding in resistance. A number of pure resistant strains have been developed, which, however, produce little or no seed when selfed and are of undetermined practical value.

The recent work of the Washington station, among others, on inheritance of smut resistance and on breeding of smut-resistant varieties is noteworthy. This station has demonstrated that smut resistance is definitely heritable, thus making possible the certain production through breeding of smut-resistant varieties.

The value of copper carbonate dust for control of cereal smut has been studied by a number of stations. The Oregon station found that high-grade dust containing 50 per cent or more of copper, when properly applied, controlled bunt in wheat, while low-grade dusts containing only 10 to 22 per cent of copper were less effective, especially when the wheat was heavily smutted. The California station found that copper carbonate dust applied to seed wheat at the rate of 2 ounces or more to the bushel effectively controlled bunt when the seed was not blackened with spores, and that the treated seed was not injured even when held in storage for an indefinite period. Bluestone powder was also found to be effective. Comparing copper carbonate and formaldehyde treatment, the North Dakota station found that the chief damage done by formaldehyde to germination resulted from too rapid drying of the seed. When the seed was placed in soil moist enough to bring about immediate germination no harm resulted. In dry soil seedlings from seed treated with formaldehyde did not grow as well as those from seed treated with copper carbonate dust. The New Jersey station secured the best control of oat smut with formaldehyde, with nearly as good results from copper and nickel carbonate.

The Minnesota station found various types of wheat, barley, and many grasses susceptible to wheat scab due to *Gibberella saubinetii*, but oats only slightly so. By artificial infection the organism was found to cause a seedling blight of flax, clover, tomato, radish, pea, and cucumber; a stem rot of squash, bean, tomato, cucumber, pea, and sunflower; a rot of apples, carrots, and potato tubers; and also a root rot of beans. Crop rotation slightly reduced the amount of disease. This station has also made extensive studies of diseases caused by *Helminthosporum sativum*, including leaf spots, root rots, foot rots, seedling blight, and discolored seeds of wheat, barley, rye, and many grasses. These studies have shown a wide range of susceptibility and of host plants of these diseases, which are extremely hard to control. Rotation helps to reduce disease, but does not eliminate it. Resistant varieties are thought to offer the most promising means of control.

Much work has been done by a number of stations on corn rots of various kinds. Observations at the Indiana station indicate that the root rots do most damage in soils deficient in available phosphates and potash and that the addition of these often corrects the trouble. Ear rots appear to be largely dependent upon climatic conditions in the fall. The Iowa station found that *Diplodia zeæ* causing dry rot of corn is not systemic and does not grow into the plant from infected seed, that heavy rainfall at the end of the growing period favors the development of the disease, and

that Diplodia-infected seed is difficult or impossible to detect except by germination tests. A long rotation, the early field selection of seed, and seed germination tests in the spring are considered to be the most promising means of control. Dry rot, due to *Basisporium gallarum*, was found by this station to infect the corn plant locally, rotting the fibers of the shanks and causing infected ears to break off easily. The temperature limits for the growth of the organism were found to be between 10° and 40° C., with an optimum of 25°.

Sugar beet diseases.—The extension of sugar beet production appears to depend in many cases upon the possible degree of control of insect-borne diseases. Some of the stations are, therefore, studying the dissemination of such diseases by insects. The California station has found that leafhoppers, not previously infected with curly leaf of sugar beets, transmitted the disease after being allowed to feed for two hours on diseased beets. A number of weeds of the Chenopodeaceæ family were found to serve as food and breeding plants for the leafhoppers, and a number of other weeds were found to harbor them under natural conditions.

Sweet potato diseases.—Rots of various kinds are responsible for large losses of sweet potatoes. The New Jersey stations found that fertilizers applied in the row increased the losses from stem rot somewhat in proportion to the size of the application.

Disease of tobacco.—Mosaic, angular leaf spot, and wildfire are among the very destructive diseases of tobacco which have been investigated by a number of stations. The Connecticut station found that tobacco mosaic overwinters on the bull nettle and ground cherry, and that a necessary protective measure is to remove these weeds from the plant bed and its surroundings. Of the plant beds examined by this station, 90 per cent were found to be infected with angular leaf spot, the source of infection in all cases being tobacco juices spit upon the young plants at weeding time. The Connecticut and Virginia stations have worked out and put into practice effective methods of controlling tobacco wildfire, depending mainly upon sterilization of seed, soil, and cover and other parts of the seed bed and the avoidance of the use of any infected tobacco or other refuse in the bed.

Conditions favorable to pole burn or shed burn of tobacco were found by the Pennsylvania station to be failure to wilt stalk-harvested leaves, especially those cut immediately after a rain and before hanging them in the shed, too close hanging, insufficient ventilation, and rainy or foggy damp weather, especially when it is also warm. The use of artificial heat at critical times effectually prevents pole burn.

Cotton diseases.—Texas root rot, a destructive disease especially of cotton, has been found by the Texas station to be capable of attacking a great number of field crops, truck crops, fruits, forest trees, shrubbery, and ornamentals. The peach crop is highly resistant and the pecan wholly so, as are all of the grain and cereal crops. There appears to be but slight difference in resistance of the various varieties of cotton. The causal organism has been definitely determined to be *Phymatotricum omnivorum*. It requires a living host on which to winter over, and infection is active both during the winter and the summer months. It is spread underground by root contact. Control methods recommended consist in eliminating from the soil all living susceptible roots during the fall and winter months by frequent cultivation, plowing when the soil is dry, and using a system of fallow and rotation with nonsusceptible hosts, and by the elimination of all weed carriers.

Fruit diseases.—An example of effective station work on fruit diseases is furnished by various investigations on apple blotch. The Pennsylvania station found that the time of infection with this disease is variable from year to year, the probable limiting factor being precipitation. Tests at the New Jersey station indicated that the disease can not be controlled by the regular spray schedule, especially where it is severe. Three additional applications of commercial concentrated lime sulphur at seven-day intervals following the fifth summer spray made four or five weeks after petal fall gave the best control. In tests at the Indiana station very weak Bordeaux sprays were effective, the early petal-fall spray being especially necessary.

The relation between resistance to brown rot in the plum and mechanical texture and crude fiber content was established by the Minnesota station, those varieties having a tough skin and firm tissue being the most resistant; but this changes from one period of ripeness to another. All varieties have the mechanical properties of resistance when only half grown,

and all have the mechanical properties of susceptibility when overripe.

Tomato wilt.—Much especially noteworthy work on tomato wilt has been recently reported by the stations. Five strains of *Fusarium lycopersici* have been isolated from wilted tomato plants by the Utah station. One of these has proved definitely pathogenic and is being used as a basis for the production of resistant forms. The Missouri station found that the fungus will grow in only a limited range of acidity and that a minimum of wilting occurred in soils of which the reaction was approximately that of the cultures in which minimum wilting occurred, suggesting the possibility of artificially producing soil reactions unfavorable for wilt.

ENTOMOLOGY

The entomological work of the year covered as usual a wide range. A few examples of this work were as follows:

Apple tree leaf roller.—As a result of studies on the apple tree leaf roller the Montana station found that in case of severe infestation this insect may be effectively controlled by use of miscible oil applied when the eggs hatch in the spring. The New York State station found that in some seasons the larvæ of this insect continue to emerge over a period of four to six weeks and that it is necessary to apply arsenicals at rather short intervals during this period, beginning with the prepink stage, in order to keep the new foliage of the terminal growth, leaves, and fruit clusters thoroughly coated with the toxic material. The Washington station found that the leaf roller shows a variety preference, 5 per cent of Rome Beauty being injured, 10 per cent of Jonathan, and 20 per cent of Delicious. Oil sprays were much more efficient than calcium arsenate, the lighter oils being better than those of medium or heavy viscosity.

Oriental fruit moth.—Experiments with the oriental fruit moth at the Virginia station showed that 40 per cent nicotine sulphate is decidedly toxic to eggs and hatching larvæ of the moth.

Trumpet apple leaf miner.—The trumpet apple leaf miner (*Tischeria malifoliella*) was the subject of extensive studies at the Iowa station with reference to life history, food plants, and control. It was found that ordinarily the usual spray schedule for apples, with the aid of natural enemies, keeps this pest in check.

Citrus aphid.—A new citrus aphid, reported by the Florida station, was identified by the Maine station as *Aphis spiræcola.* Its primary food plant is Spiræa, but it migrates to many other plants. Various parasites have been noted, but artificial control has not yet been very successful.

Strawberry crown borer.—While the strawberry is the usual host of the crown borer, the Tennessee station reports that the adults will feed on the blackberry, and the insect has been reared experimentally on the Indian strawberry (*Duchesnia indica*). In a normal year the adult beetles make their appearance and become actively engaged in ovipositing about the first week in April (in Tennessee), and egg laying continues to the end of September, while larvæ may be present from April to the last of November. Hibernation takes place in the adult stage in the strawberry patch beneath leaves and rubbish. The life cycle is generally one year.

Red mite.—The European red mite was found by the Connecticut State station to pass the winter in the egg stage on smaller twigs and branches. Eggs hatched in April or May. The incubation period of the summer egg varies from 6 to 13 days and the adult develops in 5 to 10 days. Adults live 6 to 19 days, and adult females lay 16 to 34 eggs during their lives.

San José scale.—The use of oil sprays was found by the New Mexico station to be more efficient for the control of San José scale than lime-sulphur wash. At the Illinois station summer applications of oil emulsion in addition to the dormant application proved better than the latter alone in the control of the scale.

Woolly aphis.—Paradichlorobenzene one-fourth to one-half ounce and pine tar creosote 1 quart gave temporary control of the underground form of the woolly aphis in experiments at the Tennessee station.

Mexican bean weevil.—In control of the Mexican bean weevil and other insects, sodium fluosilicate gave promising results in experiments at the Tennessee station, being both a contact insecticide and a stomach poison. It is not as poisonous to man as arsenicals. At the Alabama station it was found that the adult beetles show no preference between different varieties of *Phaseolus vulgaris.* Butter beans (*P. lunatus*) possess nearly the same attraction, but infestation of eggs and larvæ develop more slowly. Cowpeas may be at-

tacked. The beetle was economically controlled by dusting with a mixture of calcium arsenate, sulphur, and hydrated lime, 1:1:4. At the South Carolina station the poisons which gave the most encouraging results were magnesium arsenate mixed with 3 to 5 parts of hydrated lime and calcium arsenate with 9 parts of lime, applied as a dust. Lead arsenate gave good control but burned the foliage slightly.

Cabbage root maggot.—Satisfactory control of the cabbage root maggot was secured by the Pennsylvania station by the use of corrosive sublimate, 1 to 1,000. At the New York State station it was found that treatment of cabbage seed beds for maggot with corrosive sublimate solution also protected the plants from attacks of Rhizoctonia and blackleg. Both these and clubroot, as well as the maggot, were successfully controlled by the use of a 1 to 1,280 solution applied three times. Screening the seed bed with cheesecloth will control the maggot but this produces more succulent plants that are subject to Rhizoctonia. This also applies to the use of tobacco dust, which, although effective against the maggot, encourages the growth of Rhizoctonia.

Potato insects.—The favorite food plants of the potato leafhopper during the late fall after potato plants disappear are, according to the Minnesota station, boxelder, apple, rhubarb, and curly dock. In the spring, however, the adults feed almost exclusively on apple and rhubarb. Egg laying begins about June 17 and reaches a maximum by the latter part of June, the nymphal period extending from June 21 to July 15. Adults of the second generation become very abundant about July 17 and continue to increase in numbers until the latter part of the month. Eggs are laid over the period from July 20 to September 1, and overwintering adults develop from these until the middle of September.

The development of hopperburn on potatoes according to the Iowa station is dependent to a large extent upon the date of planting, due to the fact that the female leafhoppers prefer partly grown plants for oviposition rather than smaller vines at the time of the spring flight. Greatest tolerance of the disease was shown by potatoes of the Rural New Yorker type. The rate of development of hopperburn on individual leaflets was determined by the size and succulence of the leaf and not by any inherent resistance.

The green peach aphid, which is a pest of the potato, was reported for the first time, by the Maine station, as wintering in that State, a small but typical spring colony being found on the Canada plum (*Prunus nigra*). Vigorous spring colonies of the buckthorn aphis (*Aphis abbreviata*), which attacks the potato, were found on Rhamnus bordering the potato field, showing that this plant may serve as an overwintering host.

Sweet potato weevil.—Studies on the sweet potato weevil at the Louisiana station showed no clear-cut generations, but there appeared to be at least eight broods during the year. Wild morning glory and tie vines were found to be host plants, especially the large-rooted perennial morning glory (*Ipomœa pandurata*), which appeared to be as acceptable as the sweet potato. Infested seed potatoes are the most common medium of dissemination, the natural spread being very slow. Control studies of this insect at the Texas station showed that there are no parasites or predacious enemies that are of economic importance, and artificial methods of control must be used.

Squash insects.—The squash ladybird beetle, according to the Virginia station, passes the winter in the adult stage chiefly on the trunks of trees and begins to emerge from hibernation about May 20. The first eggs are laid the second week in June and hatch in seven or eight days. In late August the second brood beetles emerge, the first brood overlapping. The chief injury is inflicted by the larvæ of the first brood during the latter half of July and the first half of August. The pickle worm, which attacks especially squashes, cantaloupes, cucumbers, and muskmelons, was found by the Missouri station to show a special preference for summer squash, which when grown as a trap crop with cantaloupes, almost wholly protects the latter.

Alfalfa weevil parasite.—The parasitic hymenopter (*Bathyplectes curculionis*), an enemy of the alfalfa weevil, introduced in cooperation with the United States Department of Agriculture in 1921, has, according to the Nevada station, become fully established and is now present in all infested fields, promising to be an important factor in reducing the number of weevils.

Corn root worm.—Studies on the southern corn root worm by the Louisiana station showed injury to be more se-

vere in early plantings, from the middle of March to the middle of April. The worms were found in the roots of volunteer oats in the spring. Apparently larvæ that injure young corn come from eggs that are deposited in grasses before the corn is planted.

Cotton insects.—A number of studies of cotton insects were reported. The Kentucky station used arsenates of lime and lead successfully in the control of the cotton worm. The Arkansas station recommends destruction of the boll weevil in hibernation and the growing of early cotton. Early infestation was controlled by use of calcium arsenate dust. The Texas station reports that the so-called "rough skinned" weevil, which ordinarily breeds on the morning glory, was found to be injuring cotton by cutting off the lower leaves. The cotton hopper (*Psallus seriatus*) was found to be doing considerable damage in southern Texas, especially on land previously planted to corn or oats. It appears that the greatest injury occurs where favorable host plants are found in early spring, thus permitting the insects to multiply and become abundant when the cotton is young. At the South Carolina station this insect, comparatively new in the State, was found doing considerable damage to cotton. It causes the young terminal bud and terminal leaf to wither, turn brown or black, and drop off, resulting in a failure of the squares to develop. The insect is of the sucking type, which makes poisoning impossible.

Miscellaneous.—Studies on the Hessian fly at the Kansas station indicated that development of varietal resistance furnishes one of the most promising means of combating this pest.

The Japanese beetle can, according to the New Jersey station, be cheaply and efficiently controlled by killing the larvæ in the soil with carbon bisulphide used at the rate of 1 pound per cubic yard of soil under favorable conditions of exposure and temperature.

The pale western cutworm, according to observations by the Montana station, varies in abundance with the rainfall of May, June, and July of the year preceding the outbreak. If the rainfall is less than 4 inches for these three months, the cutworms will probably be found in increased numbers the next year, but if the rainfall is more than 5 inches, the insects will be reduced in number the next season.

Nematodes were controlled at the Florida station by the use of velvet beans as a summer crop, with cultivation and hoeing. By this means numbers were so reduced that the land could be successfully used for vegetables which are highly susceptible to nematode attack.

Beetles and weevils infesting stored seed were effectively controlled by the copper carbonate dust treatment, at the California station. The Minnesota station found that a temperature of 64° C. retards the development of the bean weevil and a temperature of —10° for 12 hours was fatal to all stages. It was found that the spider beetle (*Ptinus fur*) resisted very low temperatures and survived the coldest weather in open warehouses.

Tobacco insecticides.—The discovery of a high yielding, high nicotine tobacco, *Nicotiana rustica*, with commercial possibilities for insect control is reported by the Pennsylvania station. It was found that the nicotine content can be increased by topping or suckering the plants during their growth. The nicotine is easily obtained by pulverizing the plant, steeping in cold water or heating to boiling, and filtering. Such solutions diluted to a concentration of 0.06 to 0.2 per cent nicotine, with the addition of soap, showed marked aphicidal properties.

When acid arsenate of lead was mixed with lime-sulphur to form a combination spray, the New York State station found that undesirable chemical changes took place which could be prevented by the addition of tobacco dust, and at the same time the nicotine in the tobacco dust was dissolved and rendered readily available for insecticidal use.

ANIMAL PRODUCTION

Animal production is exceeded only by crop production and horticulture in the number of projects of investigation reported by the stations. These projects deal with fundamental questions of genetics and nutrition as well as the more practical features of breeding, feeding, and care of all classes of farm livestock. The progress and present status of station work in animal genetics are reviewed in the special article beginning on page 67. Some recent contributions to the subject of animal nutrition are as follows:

Animal nutrition.—Much of the more advanced work in animal nutrition has been along the lines of effect of plane of nutrition, energy requirements, and relation of light, vitamins, and mineral matter to nutrition.

Studies of undernutrition of steers at the New Hampshire station, in cooperation with the nutrition laboratory of the Carnegie Institution, indicated that such vital activities as pulse rate, heat production, glandular secretion, and physical activity decrease with reduced ration, the reverse being true with fattening rations. Nearly four months of undernutrition in no case impaired health, and there was no evidence that it limited the regain of flesh and fat lost. The rate of regain in steers which were brought through a whole winter on a 50 per cent maintenance ration was exceedingly rapid, the original weight being recovered in less than three months on pasture grass alone.

Rations high in protein were found by the New Hampshire station to be particularly uneconomic for fattening, the amount of protein that a mature steer assimilates daily being relatively limited. The Pennsylvania Institute of Animal Nutrition in cooperative studies with a number of stations found that normal growth can be made by cattle on rations containing an appreciably smaller proportion of protein to nonnitrogenous nutrients than is specified by Morrison's latest revision of the Wolff-Lehmann feeding standards. Allowing 0.6 pound of digestible protein for maintenance, the additional protein requirement for milk production was found to be about one and one-fourth times the protein content of the milk. The maintenance requirements of dry cows was found to vary from 4.15 to 5.57 therms of net energy per 1,000 pounds of live weight.

The basal heat production per square meter of body surface of fowls was found by the Illinois station to be nearly the same for birds varying in age from 2½ months to 1 year but decreased progressively per kilogram of body weight with the age of the bird. For birds slightly over a month old it was much greater both per square meter of body surface and per kilogram of body weight than with older birds. The heat production of cockerels was distinctly higher than that of pullets and capons, and that of pullets was generally higher, especially at the older ages, than that of capons. The heat production of cockerels per square meter of body surface was 849 calories, of pullets 807 calories, and of capons 768 calories. A formula for calculating basal heat production per square meter of body surface is proposed as follows: $S=5.86\ W^{.5}\ L^{.6}$ in which S is the surface in square centimeters, W the live weight in grams, and L the distance from rump to shoulder in centimeters.

The ash of the entire bodies of calves from dams on different planes of nutrition was found by the Missouri station to be constant in composition and, with the exception of phosphorus, not correlated with the condition of the dam. The mineral content of lean and fat was not influenced by age or condition. The mineral content of the internal organs decreased in the older animals but was apparently not affected by the method of feeding. The mineral constituents of the blood were fairly constant for all ages and groups. All of the mineral constituents of the skeleton showed an increase in the older and in the well-fed animals. The calcium and phosphorus content of the entire body increased somewhat in the older animals. The Washington station found that variations of sodium in the feed has a decided influence on the growth and condition of the animal. The sodium level, below which growth is retarded and above which it is continued, appears to be very distinct. Animals receiving the smaller quantities of sodium grew rapidly for a short time and then declined in weight, many of them dying comparatively young, while those receiving the larger quantities continued to grow in good health.

The quality of light was found by the Nebraska station to have an especial influence on calcium and phosphorus assimilation by chickens. Light coming through common window glass and deprived of most of the short or ultra-violet rays did not possess the catalytic power necessary for calcium or phosphorus absorption. An exposure to sunlight for 45 minutes a day made the difference between success and failure in growing chickens fed standard rations. In the absence of proper light conditions 3 per cent of cod liver oil added to the ration had the same influence on calcium and phosphorus absorption as sunlight. Chicks exposed to sunlight or ultra-violet rays at the Illinois station did not need antirachitic vitamin D, but chicks fed a basal ration with all the necessary vitamins supplied made as good growth in complete darkness as those exposed to light.

A group of calves kept by the Minnesota station for a year on a ration practically free from antiscorbutic vitamin showed no bad effects, while on

the same ration guinea pigs died from scurvy within 20 days. The requirement of the growing calf for this vitamin appeared to be small. Calves fed whole milk as the sole diet died of tetany within three or four months. This was prevented by adding calcium carbonate to the ration which, however, did not prevent the later appearance of a ricket-like trouble, and neither was the trouble prevented by adding vitamins A, B, or C to the milk diet. Cod liver oil lost its value as a preventive of leg weakness in chickens, in experiments at the Connecticut Storrs station, when mixed with dry feed stored for six months. The minimum amount of antirachitic substance required by chicks was supplied by a quantity of cod liver oil not exceeding 0.5 per cent of the total food intake.

Those organs and tissues of animals which are considered high in vitamin potency were found by the Kentucky station to have a greater concentration of iron, manganese, copper, and zinc than the parts considered low in vitamins. Mature pigeons maintained normal weight for seven weeks and some gained weight on rations low in vitamins, to which one or more of these mineral substances were added.

Some examples of the more practical work of the year in animal production are as follows:

Cattle.—The economy of using younger cattle in the feed lot was indicated by experiments at the Nebraska station. Young animals made more economical gains for feed consumed, could be held over a longer period in case of adverse markets, and the initial cost was less than in case of older animals. The Texas station found that under like conditions 2-year-olds gained more per steer but less per 1,000 pounds of live weight than yearlings. The average cost per 100 pounds of gain was greater for the older steers. Hogs following the steers gained more per steer with the older animals but little more in proportion to the total quantity of corn fed. The conclusion was reached that it is cheaper to ship the steers to where the feed is grown than to pay freight on feed to a convenient feeding place. At the Arizona station 3-year-old steers fattened more rapidly, reached a market finish more quickly, and produced a greater net return than did 2-year-olds when fed a ration of corn silage, alfalfa hay, and cottonseed meal.

Velvet beans were found by the South Carolina station to be a cheap and effective substitute for cottonseed meal for all classes of beef cattle.

Chamiza (*Atriplex canescens*) was shown by the New Mexico station to have a high carrying capacity as a range feed over an extended period of time, to give good succulent feed for cattle in winter as well as in summer, and to sustain a cow and enable her to produce a normal calf. The plant is so high in protein that no protein supplement is needed when pasturing on it. Experiments to establish stands of chamiza on the range indicated that it may be possible to obtain a stand without irrigation and at small expense.

Baby-beef calves can be successfully fattened in Minnesota entirely on home-grown feeds, according to the Minnesota station. Ground ear corn was used successfully and profitably in comparison with a mixture of shelled corn and oats or shelled corn alone. It did not pay to grind shelled corn for the purpose. Corn silage was used to advantage only when the grain ration was supplemented with a high protein concentrate.

Sheep.—The combined returns from lambs and wool in a grade fine-wool flock of sheep was greater, in experiments at the Pennsylvania station, when ewes were bred to mutton rams and all lambs marketed than when the ewes were bred to fine-wool rams. The lambs fattened more quickly and were more desirable for market purposes than those sired by fine-wool rams. The Ohio station found that if early spring lambs are to be raised from Merino ewes it is more profitable to breed them to Southdown than to Merino rams. Because of the early maturing qualities of the Southdown the cross-bred lambs made more rapid and economical gains and produced heavier, fatter, and better developed carcasses at an early age than the Merino lambs. The cross-bred lambs commanded a higher price and yielded a larger ratio of dressed carcass to live weight.

The importance of having ewes in good physical condition at lambing time was emphasized in experiments at the Nevada station. Special efforts to secure increased milk flow during the lambing period were of less importance than good general physical condition at the beginning of the period. The Montana station showed that as a maintenance ration for

breeding ewes alfalfa hay alone is as effective as when supplemented with grain or silage. Cottonseed cake did not improve the alfalfa ration and increased the cost of feed.

Rotative grazing on a plan by which sheep do not go on a pasture until the grass has made a good growth was shown by the Nevada station to greatly increase the carrying capacity.

Barley proved to be an economical and profitable supplement to a ration of alfalfa hay for finishing lambs for fall shipment, in experiments at the Nevada station. The addition of linseed meal to a corn and alfalfa ration caused an increase in the rate of gain, a slight increase in the cost of gain, but a large profit per lamb, in tests at the Nebraska station. The addition of alfalfa-molasses meal to a corn and alfalfa hay ration increased slightly the gains made. Addition of oats to a ration of corn and alfalfa hay was of no advantage. Alfalfa hay gave larger gains and more profit than prairie hay. The Oregon station demonstrated that high class finished lambs can be produced with home-grown feeds—alfalfa supplemented by native grains. Alfalfa hay and shelled corn as a standard ration excelled soy bean hay and shelled corn in rate of gain and quantity of feed required per 100 pounds of gain, in experiments at the Illinois station. Soy bean oil meal and linseed meal were about equally effective as supplements. Experiments at the Indiana station indicated that soy beans have a high feeding value for lambs.

Silage rations produced more rapid and economical gains than corn stover rations, in experiments at the Indiana station. Ear corn was apparently as valuable as shelled corn for fattening lambs. At the Washington station lambs receiving rations containing silage made more rapid and greater gains than those receiving hay alone as a roughage. At the Texas station it was found that ground threshed milo and kafir produced practically the same gains as ground shelled corn when fed in the same quantities as corn for fattening lambs, and the gains were made at less cost.

Swine.—In studies of the effect of early breeding of sows the Missouri station found that well-fed and well-developed sows bred at 6 to 8 months of age and twice a year thereafter produced more pigs at less cost than sows producing their first litters at 18 to 20 months of age, and that the pigs developed about as rapidly and were ready for market at nearly the same age as those from later bred sows. Breeding very young sows, however, retarded their growth.

Pigs stunted by insufficient feed were found by the Utah station to recover and make rapid and economical gains. Such pigs made gains in 25 per cent less time and on 17 per cent less feed than pigs full fed from the beginning. The Kansas station showed that exercise exerts a material beneficial effect upon the strength, thrift, and growth of pigs.

A ration of corn, soy beans, and a mineral mixture of acid phosphate, wood ashes, and salt, produced as rapid gains in fattening hogs as corn and tankage, in experiments at the Indiana station. The addition of a self-fed mineral mixture to corn and soy beans, hogged off, increased the rate of gain and lowered the cost, in experiments at this station.

In a comparison of various forms of lime as mineral additions to a standard ration for pigs at the Minnesota station, marl appeared to be a suitable material for such use. In experiments at the Illinois station the use of various mineral substances for pigs receiving corn tankage and middlings, both in dry lot and on bluegrass pasture did not give results justifying their use. Feeding mineral supplements ad libitum to growing and fattening pigs on rations containing feeds high or fairly high in calcium, such as tankage or good pasture, showed little if any effect on rate or economy of gains.

Rough rice was found by the California station to be an unsatisfactory feed for hogs, but rice polish, rice bran, and brewers' rice, supplemented with some animal protein, were satisfactory. In experiments at the Texas station rice bran showed a money value only 57 per cent as great as corn for pigs during the growing period but 70 per cent as great during the fattening period, measured by the amount of feed required to make a pound of gain. As compared with corn, rice bran invariably lowered the average daily gain and increased the quantity of feed required per unit of gain. The rice bran produced soft pork when fed for 150 days.

Hogs fed on soy bean forage with 2 per cent corn for 71 days produced soft pork, in experiments at the South Carolina station. In preliminary tests at the Georgia station the feeding of velvet beans to hogs showed a softening effect on the pork. In experiments at the Mississippi station, however, no such effect was noted.

In grazing experiments at the Mississippi station in which soy beans and corn were grown together, it was found to be usually most economical to gather the corn and graze the beans, hand feeding the corn in quantities up to 2.5 per cent of the live weight of the hogs.

Garbage alone did not prove to be as economical as garbage supplemented with barley as a feed for growing pigs, in experiments at the Wyoming station.

White and yellow corn appeared to be of equal feeding value for mature hogs, in experiments at the Illinois station, but young growing pigs did not do well on a ration of white corn and tankage, although those on yellow corn and tankage made normal growth. In winter feeding experiments at the West Virginia station yellow corn proved superior to white.

In a comparison of fish meal, tankage, oil cake, and oil meal with corn, at the Pennsylvania station, pigs fed fish meal made the largest gain, and no undesirable results followed the use of fish meal as a feed for brood sows, the strength and quality of the litters being as good as in case of sows receiving tankage or oats and middlings. Fish meal also gave the best returns at the Florida station in a comparison of fish meal, tankage, and linseed meal.

Barley appeared to be more palatable and to give a little more rapid gain than rye in experiments at the Montana station. In experiments at the Kentucky station the best results were obtained with whole barley soaked 24 hours with the addition of a self-fed mineral mixture. Grinding barley increased its value from 7 to 10 per cent in experiments at the Oklahoma station. Soaking lessened its feed value. There was a slight advantage in feeding whole or ground barley in the self-feeder. One part of tankage to 12 or 13 parts of barley appeared to be the best proportion.

Poultry.—Most of the stations are engaged in some line of poultry investigation. More than 170 projects were reported as active during the year. Among the investigations of special interest reported upon were those dealing with the effect of inbreeding; breeding for egg production, fertility, and hatchability; effect of time of hatching, feeding, and molting on egg production; effect of light, vitamins, and mineral matter. The progress of the breeding work is reviewed in the special article beginning on page 67.

Leghorn chicks hatched in April gave the highest egg production in 3-year records at the Utah station, while the lowest record was made by chicks hatched in March. The Missouri station found that the average length of time required to mature White Leghorn pullets, from hatching to date of first egg, was 232 days. Those which matured in less than the average time were superior in production, down to a maturing time of less than 200 days. The West Virginia station found that the younger the pullets when beginning to lay the smaller were the first eggs laid. The maximum egg production was reached in April or May. Pullet eggs increased in weight from the beginning to the end of the first laying period. In case of yearling hens the lightest eggs were laid during the summer months.

Slow molt and low egg production were found by the Iowa station to be closely correlated. When the ration was deficient in animal protein the molt was earlier than when a full protein ration was fed. The Utah station found that pullets maturing in less than 200 days laid during the early fall and then went into a winter molt which greatly handicapped their egg record for the year following.

Several of the stations have shown the advantage of animal protein and milk and milk products in the ration for laying hens. The West Virginia station noted that chicks which received a liberal quantity of protein of animal origin while young developed more rapidly and began to lay at an earlier age than those receiving a limited protein ration. The Minnesota station reports that without animal food or with only a small quantity, the mortality of White Leghorn chicks was very heavy and the gains in weight insignificant. The Pennsylvania station found that hens receiving a milk product in addition to a standard ration produced more eggs but at a higher cost than those receiving meat scraps and vegetable proteins plus a mineral mixture. The Idaho station in a comparison of various animal and vegetable protein supplements found that a ration containing pea meal and sour milk gave exceptionally good results in stimulating egg production and reducing the cost.

Artificial illumination was of no practical advantage as measured by the yearly egg production in experiments at the Pennsylvania station.

On the other hand, the Iowa station reports that where lights were used during January and February in the breeding pens from late afternoon to 7 p. m. egg production was stimulated, fertility and hatchability were not lowered, and a larger number of early hatched chicks was obtained. At the Kansas station exposing White Leghorn pullets to ultra-violet light for 10 minutes twice a day increased egg production and the hatchability of the eggs.

Polyneuritis developed in experiments at the Indiana station in cockerels fed degerminated corn for three weeks, but the birds were restored to health by feeding corn germs for one week. It was found that birds fed a high protein diet required a greater amount of vitamin B to protect them against polyneuritis than those fed on a low protein diet.

Twice as many eggs were obtained at the Kentucky station from hens fed a diet of corn and buttermilk with limestone as from those fed corn and grain tankage mash with limestone or corn and buttermilk without limestone. There was also a distinct increase in size of egg and thickness of shell. The calcium in rock phosphate appeared to be used by the hen for the production of bone but not in the formation of eggshell, while that in calcium carbonate was used for both purposes. Deficiency of calcium in the diet retarded the development of bone. The omission of grit from the diet of hens in confinement during the first eight months of their laying period did not affect either their egg production or physical condition.

In a series of incubation experiments the Indiana station found that a temperature of 101° F. throughout the period of incubation gave the best hatching results. White eggs pipped and hatched a few hours earlier than brown at the same temperature and consistently gave better hatches. Temperatures below the optimum of 100 to 103° delayed hatching and temperatures above this hastened hatching with a large number of undesirable chicks. The temperature of incubation showed a positive relation to the total number of dead embryos during incubation. The individuality of the hen appears to have an influence on the hatching of eggs at any temperature.

DAIRYING

Investigations in dairying cover a wide range in breeding, feeding, and care of dairy animals and the handling of milk and milk products.

Comparison of feeds.—A number of stations have investigated the value of soy bean hay for milk production. At the Pennsylvania station it proved slightly inferior to alfalfa hay for milk production. At the West Virginia station results of comparative tests were inconclusive. The South Dakota station found even inferior soy bean hay equal to alfalfa hay for milk production. At the Illinois station soy bean hay was found to be equal to alfalfa hay on the basis of hay actually consumed. This station found soy bean oil meal to be very palatable and to exert no undesirable physiological effects. It compared favorably with choice cottonseed meal as a protein concentrate for milk production. In tests at the Maryland station with soy bean hay to balance a dairy ration and as a substitute for wheat bran, the bran ration produced more milk and butterfat but the cost of the product was less with the soy bean hay ration.

Velvet beans gave good results in experiments at the South Carolina station when fed to dairy cows up to 50 per cent of a palatable grain mixture.

The use of corn fodder instead of corn silage reduced milk production 6 per cent and fat production 3 per cent, in experiments at the Iowa station. The Utah station found 2½ to 3 tons of corn silage equal to 1 ton of alfalfa hay for milk production. The vitamin C content of milk from cows fed silage was found by the South Dakota station to be much greater than that of milk from cows which were not fed silage. Sunflower silage proved to be cheaper and no less effective than oat and pea silage as a ration for milch cows in experiments at the Montana station.

Cows on a subnormal ration at the Missouri station showed a decided increase in the percentage of fat in the milk produced, the peak of the increase being reached about the end of the third day and remaining abnormally high for the 10 days the reduced ration was continued. When the ration was brought back to normal the percentage of fat decreased and remained below normal for the succeeding 10-day period. The quantity of milk was reduced, depending upon the length of the feed reduction period and the stage of the lactation period. The total yield of fat was not significantly changed.

The speed of milk secretion in unit time was found by the Missouri station to be governed by the amount of milk accumulated in the udder, or the interval between milkings. Taking the amount of milk secreted during the first hour as 100 per cent, the amount secreted each succeeding hour was approximately 95 per cent of that secreted during the preceding hour. The data indicate that the percentage of fat and total solids gradually decreased with the length of the interval between milkings, until the time interval exceeds 14 to 16 hours, thereafter slightly increasing up to the twenty-fourth to twenty-sixth hour, followed again by a gradual decline to the thirty-sixth hour.

Preservation of milk.—Milk charged with carbon dioxide under a pressure of 180 pounds at 40° F. was found by the Illinois station to keep sweet for 32 days and was practically sterile at the end of the storage period, even though its initial bacterial content was 100,000 per cubic centimeter. Physical changes, however, took place which affected the quality of the milk.

The storage temperature for bottled milk should be as close to freezing as possible (33° to 35° F.) in order to get the deepest cream line, according to results at the Pennsylvania station. The deepest cream layer appeared at the end of two hours when the samples were stored at 35°, after which time the cream layer contracted. Clarification and pumping of cold milk reduced the cream layer slightly, but pumping hot Pasteurized milk did not reduce the layer. Pasteurizing milk in a glass-lined vat at 144° to 145° for 30 minutes, followed by rapid cooling over a surface cooler caused a noticeable reduction of the cream line. It was found that evaporation by air blast or vacuum methods did not reduce the vitamin B content appreciably. After sterilization of the evaporated milk the destructive effect was more marked, particularly in sterilized milk made by the air blast method.

Rate of growth of heifers.—The amount of growth of heifers during a given unit of time at any age tends, according to the Missouri station, to be a constant percentage of the growth made during the preceding unit of time. Thus the growth in height at withers during any year is about 34 per cent of the growth made during the preceding year, and the growth in weight is about 56 per cent of that of the preceding year.

Flavors in milk and milk products.—Iron bacteria were found by the California station in about 25 per cent of the milk and butter of the State, and there was evidence that off flavors can be ascribed to their presence. In experiments at the New York Cornell station butter made from neutralized pasteurized cream had a better flavor than that made from the same cream unneutralized, whether raw or pasteurized. The butter made from neutralized cream did not keep much better than that from unneutralized, although the storage temperature in this case was relatively high (50° F.). The Wisconsin station found that the conditions which favor the development of fishiness in butter are high acidity of the cream, high salt content of the butter, overworking of the butter, and the presence of iron or copper salts. It was also found that lecithin in butter undergoes a purely chemical decomposition at room or incubation temperatures, yielding trimethylamine, the cause of fishy flavor. Trimethylamine was isolated from samples of fishy butter examined. An organism, *Bacterium ichthyosmius*, isolated from cream produced trimethylamine from lecithin under favorable conditions but not in the presence of salt and under acid conditions. It is believed to be unlikely that these bacteria cause fishiness, but that this is due to the chemical decomposition of lecithin normally present in butter. Pasteurization tended to eliminate fishiness.

Cheese of better flavor was obtained from clarified milk than from unclarified, in experiments at the Utah station. The same result was obtained by the Pennsylvania station, except where milk of poor quality was handled under ordinary creamery conditions.

Ice cream.—Low acid mixes (0.15 to 0.2 per cent) for ice cream gave a better flavored and better bodied product than high, in experiments at the Illinois station. The use of dehydrated egg yolks in the mix improved the texture and resistance of ice cream but imparted a pronounced egg flavor. The kind of milk products used in the mix affected the texture and flavor of ice cream. Homogenization improved the body of ice cream, increased the amount of overrun obtainable, and yielded a good ice cream with less milk solids. The percentage of overrun obtained had a marked effect upon the quality of the ice cream. The Pennsylvania station

found no relation between acidity at time of freezing and quality of the finished ice cream, but there was a relation between acidity of the mix and the melting properties of the finished cream. The bacterial content of the mix appeared to bear no relation to the quality of the cream. The Minnesota station found that the viscosity of ice cream mixes increased when held at low temperatures. When the mix was aged at 40° F. there was no increase in acidity.

VETERINARY SCIENCE

Investigation of animal diseases is one of the major lines of station work. A wide range of diseases of general as well as local importance has been investigated. Of the 5,000 or more research projects reported as active during the year, 193 related to animal diseases (including plant poisoning, especially on the ranges). Among the diseases upon which particularly significant work was reported were infectious abortion, tuberculosis, anthrax, hemorrhagic disease (icterohemoglobinuria), and botulism. Plant poisoning also receives much attention.

Infectious abortion is a widespread menace to farm livestock. Several stations are studying it with varying degrees of success. Means of transmission and effective control have been particularly baffling.

The California, Connecticut Storrs, Kentucky, Illinois, Michigan, Minnesota, Missouri, and Montana stations have made important recent contributions to the subject, especially along the lines of the chronic character of the disease and its transmission by carriers, vaccinated animals, and through milk and otherwise, the varying virulence of different strains of the causal organism, immunity of offspring of infected mothers, immunizing value of live abortion vaccines, transmission of the disease from cattle to swine, and other causes of abortion besides *Bacillus abortus*.

Several of the stations have demonstrated that animals once infected with abortion may remain carriers of the disease for an indefinite period. Moreover, as the California station has shown, vaccinated animals may become spreaders of the disease and can not therefore with safety be kept in uninfected herds.

In tests made by the Connecticut Storrs station calves were negative when born, but within a few hours after nursing positive cows became positive. However, they became negative by the time they were 5 or 6 months of age and remained so until they received a new infection from without. The California station found that it is not necessary to protect calves from infection through the medium of milk during the milk-drinking stage, but that they must be protected after breeding age, prior to and following breeding, to prevent abortion in the first pregnancy. The Michigan station found it improbable that *B. abortus* persists in the tissue of new-born calves from a prenatal infection or through injection of milk containing *B. abortus*. There was no evidence to show that calves from infected cows were more susceptible to calves' diseases or that breeding efficiency was impaired.

The California and Minnesota stations found live abortion vaccine to have some immunizing value in bovine abortion. The Michigan station used a nonvirulent living culture of *B. abortus* with very satisfactory results in immunizing cattle which were not already infected with the disease. The Illinois station obtained like results with such vaccine in case of swine abortion.

The Michigan station reports that swine possess a high degree of natural resistance to infection by *B. abortus* and that the feeding of infected milk or association with infected cattle is not dangerous so far as the possibility of infecting swine is concerned.

The Connecticut Storrs station observed wide variations in the virulence of different strains of *B. abortus* but no marked differences in morphology and cultural characters.

Eradication of the disease from a herd has been found to be a slow and somewhat uncertain process. The Connecticut Storrs station reports the elimination of the disease from a herd in seven years by promptly disposing of aborters and gradually eliminating old reacting cows. The Missouri station is using a similar method with some success.

The Montana station reports a study of abortion in sheep due to a Spirillum or Vibrio in contaminated drinking water, which caused losses of as high as 75 per cent of the lambs of affected range flocks. The station has devised a simple blood test whereby blood from aborting ewes can be distinguished.

Tuberculosis.—Much of the recent work of the stations on tuberculosis has dealt with the avian form of this disease. The Ilinois, North Dakota, and Wyoming stations find that avian

tuberculosis is readily transmitted to swine by injection and orally. An examination of a large number of cases of swine tuberculosis by the Nebraska station showed that 88.4 per cent was of the avian type. The Wyoming station by injection of cultures of avian tuberculosis in calves produced the so-called skin form of the disease which, however, could be removed and apparently cured by surgical operation. The Minnesota station failed to find positive evidence of turbercle bacilli in eggs of tuberculous fowls.

Anthrax.—The high virulence and viability of the anthrax organism has received further confirmation by investigations at the Louisiana station. This station found that the organism retained its virulence for three years in a soil alternately moistened and dried. *Tabanus fulvulus* was found to be an active carrier of the disease. Evidence was secured that the disease can be controlled by immunization.

In case of the obscure and baffling hemorrhagic disease known as icterohemoglobinuria which has been responsible for considerable losses of livestock, the Nevada station has successfully isolated the causal organism and succeeded in cultivating it and producing a serum of high curative potency. These results promise much from the standpoint of effective control of the disease.

Botulism has caused much alarm from the standpoint of its deadly effect on domestic animals as well as on man. The Illinois station has shown the varying effects of several types of avian botulism, and the Colorado station has reported the wide distribution of *B. botulinus* in virgin and cultivated soils.

Plant poisoning.—Among the poisonous or supposedly poisonous plants recently reported upon are saltbush (*Atriplex canescens* and *Artemisia spinescens*), chokecherry (*Prunus demissa*), low larkspur (*Delphinium andersonii*), and spring rabbit brush (*Tetradymia glabrata*) by the Nevada station; *Drymaria glauca* by the New Mexico station; and white snakeroot (*Eupatorium urticæfolium*) by the Indiana station. Saltbush as an exclusive feed caused sheep to abort. The chokecherry was found to be highly poisonous to sheep and cattle in the early summer. The low larkspur was found to be poisonous to cattle but not to sheep. The plant was found to contain 1.75 per cent of alkaloid calculated as delphinin ($C_{31}H_{49}O_7N$). Hungry sheep sometimes eat enough of the tender growth of rabbit brush in the spring to kill them. The poisonous property has not been determined nor a remedy found. *D. glauca* is a little known plant of limited habitat, known to be poisonous to cattle in New Mexico. The Indiana station found all farm animals susceptible to white snakeroot poisoning.

AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

Cost of production and farm organization.—The California station in a study of the business of 246 dairies in 11 dairying sections of the State for the year ended March 1, 1923, found that the cost per 100 pounds of whole milk ranged from $2.23 in the Kern district to $3.73 in the Los Angeles-Orange district, and that per pound of butterfat from 50 to 97 cents for the same districts. The New York Cornell station found the net cow cost of producing 100 pounds of milk on 83 farms in Chenango County to have been $2.73 and the herd cost $2.81. A loss of 69 cents per 100 pounds of milk sold is recorded, and after all charges except labor were met a return of 3.2 cents per hour for all the time spent on the enterprise.

In a study of the cost of producing apples in Minnesota from 1916 to 1920, an average gross return per acre of $215.99, ranging from $23.75 to $506.81, was shown by the station on the basis of 135.8 bushels of packed apples at $1.53 per bushel, 2 bushels used at home at the same price, and 12 bushels of culls at 43 cents a bushel. Comparing the profits from an apple orchard in the State for two 10-year periods, 1904–1913 and 1914–1923, the New York State station found the annual cost of tillage in the first decade to have been $7.39 per acre and in the second $14.40. The cost per barrel amounted to 6.6 and 11.7 cents, respectively. The average net profit per acre in the first decade was $95.60 and in the second $145.83.

The total cost per average litter of 5.5 pigs was found by the Oregon station to be $31.28, the final cost of growing a pig from weaning to maturity or from 30 to 200 pounds live weight, $12.85, and the total cost of a 200-pound pig, $18.54. The Missouri station found that 1.71 hours of man labor and 0.11 hour of horse labor were required to care for the average farm hen for one year. The average cost of keeping poultry through 11 years was $1.18 and the total income $1.67 per hen per year.

In a study of the amounts and distribution of labor and materials used in the production of different crops and classes of livestock, conducted by the Minnesota station in Cottonwood and Jackson Counties by the complete cost route method, it was brought out that on 22 of the 65 farms under study the miscellaneous work about the farm consumed from 5.2 to 25.1 per cent of the total man labor expended and from 2 to 15.9 per cent of the total horse labor. The Wisconsin station found that on 262 farms in Walworth County 80 per cent of the income was derived from dairying. The average labor income for the year ended May, 1921, was —$595. The labor incomes on the successful farms ranged from $318 for farms of less than 60 acres to $819 for those of more than 180 acres. Farms having five or more sources of income had an average farm income of $1,504. Dairy herds averaging more than 7,000 pounds of milk per cow produced at a cost of 40 cents per hundredweight less than herds producing between 5,000 and 7,000 pounds and $1.19 less than herds whose production did not exceed 5,000 pounds per cow.

A study by the Kentucky station of 241 farms in Mason and Fleming Counties for the farm year 1922 indicated that the average farmer made a labor income of $1,029, while the best 15 farmers earned an average of $3,203. The average total receipts were $3,714 per farm and for the best 15 farms $7,124. The average value of the perquisites furnished by the farm for the living of the operator's family was $332 per farm and for the best 15 farms $422.

A study made by the New York Cornell station in dairy sections of Chenango, Broome, and Delaware Counties showed that the average annual cost of operating a truck, exclusive of the cost of a driver, in the year ended September, 1921 was $395. The average cost per mile for second-hand trucks was 8.3 cents, as compared with 11.8 cents for 41 which were bought new. The average cost per ton-mile of hauling, less the expense of the driver, was 16.2 cents by truck and 25.7 cents with horses and wagons, while the cost of a driver for horses added 14.6 cents, as compared with 5.3 cents for trucks. The introduction of trucks into these dairy sections is held to have extended the market milk territory farther back into the hill country.

Marketing.—A study by the Ohio station of cooperative livestock shipping associations in eight counties of the State brought out a wide divergence in the weights and prices at which livestock is marketed in different counties in the State. The total expense of marketing each 200 pounds of hogs sold in 1922 ranged from $1.01 to $1.63, averaging $1.29. The net return to the farmer ranged from $18.07 to $19.17 and averaged $18.61.

A study by the Kansas station indicated that in general the milk supply of six representative cities in the State came from near-by farms. More adequate inspection and grading and more efficient methods of delivery were deemed advisable. The Pennsylvania station found that Altoona offered an active market for locally produced eggs and poultry of good quality and that 8 per cent of the potatoes, a large part of the vegetables, all of the raspberries, 69 per cent of the apples, and 7 per cent of the grapes used were produced locally.

Land tenure.—In a survey made in 1920 the Nebraska station found tenancy to be increasing rapidly when measured by acreages, farm values, or the number of farms, although two-fifths of the farms studied were not rented at all during the decade preceding the survey and one-third of the farmers of all tenures had been on the same farms for more than 10 years. The Iowa station in a study made in Cedar County found that 59.2 per cent of the farms were operated by owners and owners who rented some additional land. The percentage of owner farms had decreased from 72 in 1910 to 62 in 1919, while tenant-operated farms had increased from 28 per cent in 1910 to 38 per cent in 1919 and to 40.8 per cent in 1920.

Detailed intensive studies and field surveys made by the California station in selected districts in the State indicated that fruit properties when leased, which was said to be in exceptional cases, were usually closely supervised and such leases followed a fairly uniform type. Dairies or lands for dairying purposes were leased by both cash and share methods, as was also land for truck crops. Very little leasing of poultry farms was practiced. The majority of ranges and livestock ranches were leased for cash.

Land valuation and taxation.—From a statistical study made in Brazos, Williamson, and Dallas Counties, the Texas station showed that the ratio of share rent to land value fell with a drop in prices or poor crop, and conversely that when there was a

tendency for share rental to rise through a series of years land values very soon rose and the ratio of rents to land values diminished even though the value of share rent continued to rise. The lowest rate of return was found on the best land for the reason that here the tendency was for rents to rise most rapidly, and as a result the landlord had capitalized future increases as well as the rent.

Records of sales of real estate in the State were analyzed by the Kansas station, the conclusion reached being that small properties are over-assessed. The inequality in the assessment of farm real estate, taking the counties as taxing units, has decreased during the last 10 years, however. The inequality in the rate of assessment among individual parcels of farm real estate is held to be nearly 14 times as important as inequalities in the assessment of farm real estate, taking the county as a whole as the unit, from the standpoint of the amount of taxes levied on over-assessed properties in excess of legal requirements.

Rural community organization and farm life.—Out of 150 answers to a questionnaire sent out by the New York Cornell station in Otsego County, 26 indicated that the neighborhoods which they represented had no school or that the school was closed, and 95 reported no community use being made of the school. Of 122 schools for which reports were made, 3 or 4 indicated a definite effort to do more than regular school work. The Wisconsin station found that of 29 towns and villages in Dane County, exclusive of the city of Madison, 23 performed several fundamental economic and social services. Five types of services were found and eight types of service agencies were identified. In 11 small towns in this area there were found to be more agencies per total population in trades and repair, communication and transportation, finance, religious, and educational types than of personal, professional, and social organization activities.

Mapping country parishes and investigating the local history of rural religious organizations in Dane County, the Wisconsin station defined three streams of settlement from Europe and the eastern States corresponding to the major religious groups, including Lutheran, Roman Catholic, and Reformed Churches. There was found to be a rough correspondence between the parish boundaries of churches located in villages and small towns and the trade areas of these various centers. Churches located in a trade center were as successful in reaching the farmers as were those in the open country.

A study by the New York Cornell station of the movement of farm population from 1,110 farms in four counties in New York showed that from 1917 to 1920 men and boys were leaving at about two and one-half times the rate at which they were being produced. The rate had changed from 12 per cent for those born between 1830 and 1839 to 56 per cent for those born between 1890 and 1899. The rate for women changed in the same time from 12 to 60 per cent. Out of 699 Livingston County farmers, on the average the men who stayed on their fathers' farms had profited financially and those who had always been on farms were better off than those who had tried some other occupation for a year or more.

From a survey by the same station of certain townships of Livington County, the correlation between size of business as measured by acres, capital, and work units and the standard of living was calculated to be about 0.4. Living conditions in tenant homes compared very favorably with those in owner homes. Approximately half of the families giving the larger amounts for church support appeared to be enjoying relatively high living standards. Parents with the higher education were found to be enjoying relatively higher standards and employing more capital and labor. The Missouri station found that the cost of family living did not vary as farm labor incomes but followed more closely the trend of retail prices. The value of products furnished by the farm was one-fifth of the total living cost.

AGRICULTURAL ENGINEERING

Tillage machinery.—The Missouri station obtained an average plow draft of 5.04 pounds per square inch of furrow slice in corn stubble in 150 tests. Soil moisture content was found by the Nebraska station to be the most difficult factor, affecting plow draft, to control. It has a rather pronounced effect upon draft, chiefly because of its influence on the compactness and shearing strength of soils. At low compactions of the soil the plow draft decreases slightly with an increase in moisture content up to about 17 per cent. As the moisture increases from this point the draft increases slightly. It also increases

uniformly with an increase in the degree of compactness, this increase being about 80 per cent between compactions corresponding to volume weights of from 64 to 76 pounds per cubic foot of soil.

In dry sandy soil having a negative value of the spreading coefficient of the soil solution and a bearing power less than the pressure imposed, the Alabama station found that the coefficient of sliding friction of chilled plow iron with a polished surface varies with the speed of passage, is proportional to the pressure per unit area, and varies with the smoothness of the metal surface and the materials composing it. When the bearing power of the soil is greater than the pressure imposed per unit area and the value of the spreading coefficient of the soil solution is negative, the magnitude of the friction is proportional to the total pressure between the two surfaces, and the coefficient of friction depends upon the roughness of and the materials composing the metal surface and is independent of the area of contact and the speed of sliding. When there is enough moisture present to cause the soil to adhere to the metal surface but not to leave any moisture thereon, the coefficient of friction varies with the speed, the area of contact, the pressure per unit area, the surface and kind of metal, and the surface tension of the soil moisture film. In these circumstances the friction coefficient therefore also varies with the content of colloidal matter and moisture in the soil, and with the temperature and viscosity of the soil solution. When there is sufficient moisture present in the soil to produce a lubricating effect, the coefficient of friction varies with the pressure per unit area, the speed, the amount of moisture present, and the viscosity of the soil solution. The indication is that the coefficient of sliding friction of metal in soils is a dynamic and constantly varying factor and is governed in any soil chiefly by the moisture content and the size of soil particles.

Tractors.—The California station showed that by plotting a curve between the quantities of dust caught on the several cloths of an absolute air cleaner for a tractor motor and the number of cloths, it was possible to determine the additional quantity that would have been caught if a definite number of cloths were used. It was thus possible to determine the composition of an absolute cleaner. It was also found that every air cleaner built can be made to test 100 per cent efficient if a shrewd choice is made of the dust to be fed into it. The particles must be large enough so that they can not pass the filter and must be heavy enough so that inertia or gravity will leave them behind when the air going toward the carburetor swings around a turn. It was further found that the quantity of dust inspired by any cleaner or carburetor is greatly reduced if the intake is placed high and faces away from the direction of motion of the tractor.

Wagon draft.—The results of 164 tests at the Missouri station checked closely with the rule that the draft of wagons, under various road and field conditions and with different sizes of wheels and widths of tires, varies directly with the load and inversely with the radius of the wheel than with rules using the square root or the cube root of the radius. Wide tires decreased the draft. Coefficients of rolling friction of 0.508 for worn brick pavement, 0.366 for new brick pavement, 0.417 for concrete pavement, 1.814 for dry dirt road, 1.98 for muddy dirt road, 0.565 for gravel road, and 0.755 for cinder road were established.

Silage cutters.—The Wisconsin station showed that available silage cutters have much greater capacities than is ordinarily assumed and that 15- or 16-inch flywheel machines and 18- or 20-inch cylinder machines have much more capacity at present rated speeds than any ordinary crew of men can supply, proving that larger machines are unnecessary. Such machines could be operated at speeds approximately 40 per cent slower than recommended speeds and still have sufficient capacity for ordinary requirements, thus resulting in much greater efficiency. The real capacity of the silage cutter was found to be proportional to its speed. It was proved that at slow speeds high efficiency can be obtained, the quality of cutting is excellent if the knives are set quite close, wear and tear is less, and a machine can be designed to elevate properly. In most cases the efficiency was affected but little by moderate variations in the capacity, with a slight tendency toward better efficiency with higher capacity.

Marl excavating equipment.—The Michigan station showed that pumping is the most successful process for marl excavation from the mechanical standpoint, but involves a considerable investment and overhead cost for operating. A special agitator was developed consisting of a rotating propeller-like cutter surrounded by a large

hood attached to the end of the suction pipe. This hood was allowed to sink into the marl, which was agitated, mixed with water, and pumped. Where a large investment for equipment in large sizes is permissible, the slack-line-cableway excavator is permissible, although generally not economically installed. It was found necessary with this equipment to control the depth to which the excavator bucket cuts and to employ mechanical means for emptying the bucket of the sticky material.

Drainage.—The Minnesota station found that the downward penetration of corn roots in peat soils is bounded by a zone sharply defined by the flattening out of the .roots within it. This zone is not more than 3 inches thick and is not at or near the water table. Its underside, beyond which the roots do not penetrate, is approximately 18 inches above and parallel to the water table. These results have an important bearing on the design of drainage systems to control the water level in marsh soils.

Duty of water in irrigation.—The Utah station found that where water is available at a given price the economical number of acre-inches of water to apply per acre is independent of the cost of plowing, seeding, fertilizing, etc., since this cost is not a function of the ratio of the cost of water per acre-inch to the price per ton of the crop on the farm. The maximum profit per acre will be obtained with some quantity of water less than the amount necessary to obtain the maximum yield. Where a large area of land is available but the water supply is limited and it is desired under these circumstances to obtain the maximum profit for the entire area, the price of the water does not influence the quantity of water for each acre which will bring such maximum profit. However, if the most economical quantity of water is used on each acre, the total profits decrease as the cost of the water increases, and vice versa. Increasing the cost of ditching and application of water is equivalent to increasing the cost of plowing, seeding, fertilizing, etc. This indicates that it will pay better to use more water per acre than to spread it over a large area by the use of more ditches and labor.

Alkali soils.—The New Mexico station showed that the use of aluminum sulphate even in small percentages increased the permeability of irrigated soils sufficiently to indicate that small areas of such soil may be profitably improved by this treatment. As much as 2 per cent of aluminum sulphate could be added to alkali soils with a high content of calcium carbonate without toxic effects.

Biology of sewage disposal.—The New Jersey stations showed that the bulk of the downflowing sewage does not filter through the film around the stones of a sprinkling filter. Solutions of certain chemicals of many times the concentration necessary to kill protozoa exposed directly to them had no effect on the protozoa in the film during the period of a normal spray on the beds. The largest numbers of either reducing or oxidizing bacteria per cubic centimeter were found in the digestive chamber of the Imhoff tank of a sewage treatment plant. The effluent from the sprinkling filter normally contained the fewest bacteria per cubic centimeter. The organisms most important numerically throughout the plant were the nitrate reducers, hydrogen sulphide producers, and the albumin digesters. Nitrifying and sulphur-oxidizing bacteria occurred throughout the plant and were consistently found even in the digestion chamber of the Imhoff tank. The numbers of nitrifying bacteria increased in the filter bed, although they never became numerically predominant, and they occurred in higher percentages in liquid which had trickled through the lower levels of the bed than in that collected near the surface. The numbers of hydrogen-sulphide producing organisms decreased as the sewage passed through the plant. A higher nitrate production was found to occur in the lower than in the upper levels of a sprinkling filter.

Draintile.—The Minnesota station showed that concrete tile for use in peat soils should be steam cured and should have an absorption of less than 7 per cent of the dry weight and a breaking strength of not less than 1,600 pounds per linear foot for all 30-day-old tile up to 16 inches in diameter, with an increase of 100 pounds for each inch in diameter thereafter. A strength two-thirds as great as this is permissible for concrete tile laid in a clay subsoil and for shale tile in any soil for all depths down to 6 feet. At greater depths the greater strength is required for both shale and concrete tile.

Soil erosion.—The Missouri station showed that deep plowing (8 inches) is only slightly more effective than shallow plowing (4 inches) in preventing run-off and erosion. A growing crop, particularly small grain or sod, furnishes the most effective means of reducing erosion.

PRESENT STATUS OF HOME ECONOMICS RESEARCH AT THE AGRICULTURAL EXPERIMENT STATIONS

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SCOPE OF SURVEY

This paper represents an attempt to ascertain the present status of home economics research in the agricultural experiment stations,[1] as distinct from that of the land-grant colleges as a whole, a survey of which was reported at the 1924 meeting of the Association of Land-Grant Colleges.[2] The sources of information in the present survey were in all cases the reports received in reply to a circular letter sent in 1924 to the director of each station, requesting a complete list of research projects under active investigation.

In selecting from the long lists of projects submitted those of possible bearing on home economics, the following definition of home economics research proposed by the committee which made the survey of home economics research in the land-grant colleges referred to above has been kept in mind:

> Research in home economics includes all study by the experimental method (namely, the assembling of observations and facts under conditions which permit a cause and effect interpretation and deduction therefrom of principles which form the basis of knowledge) of all the phenomena and factors which are involved in home life, and of the problems growing out of homes and their interrelationships.

In classifying the projects selected, the four main divisions under which the work of the Bureau of Home Economics of the Department of Agriculture is being conducted have been used. These are: (1) Food and nutrition, (2) clothing and textiles, (3) economic and social, and (4) household equipment. The accompanying tabulation thus indicates in a general way the stations most actively engaged in work pertaining to home economics, the research departments of the stations in which work related to home economics is being carried on, and the phases of home economics research at present receiving special attention.

As far as could be judged by the statements of projects, 17 of the 50 stations included in the survey[3] are not engaged in any research which has direct application to home economics, and only 4 of the stations report research projects conducted in home economics departments as such. On the other hand, the list of departments whose research projects appear to have a bearing on some phase of home economics as summarized below is encouraging and furnishes an excellent verification of the statement made by Dr. R. W. Thatcher in his paper on The Field of Research in Home Economics at the 1924 meeting of the Association of Land-Grant Colleges[4] to the effect that—

> There are many fine projects of research which are being carried on in departments of chemistry, physiology, bacteriology, economics, sociology, etc., which have a very definite application to the problems of home life. These are as truly research in home economics as if they were organized, administered, and prosecuted by members of home economics staffs.

The list is perhaps not complete, but it shows a total of 130 projects at 33 stations carried on in 14 different departments, as follows:

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[1] For an editorial review of the subject, see Experiment Station Record, 40 (1922), p. 601.
[2] Assoc. Land-Grant Cols. Proc., 1924, p. 399.
[3] The stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands are not included.
[4] Assoc. Land-Grant Cols. Proc., 1924, p. 393.

Experiment Station projects of application to home economics, 1924

Station	Station department conducting the research	Phase of home economics concerned	Title of project
Alabama	Animal industry	Food and nutrition	The vitamin content of certain nuts.
Do	Agricultural engineering.	Household equipment.	Requirement for farm refrigeration outfits. Temperature and impact requirements of dish-washing machines.
Arkansas	Agricultural chemistry.	Food and nutrition	Dietary requirements for reproduction. Cause of inadequacy of milk proteins for reproduction. Iron content of certain foods.
California	Dairy industry and fruit products.	do	Fruit in ice cream.
Do	Nutrition	do	Study of California foods and food products with respect to content of vitamin C.
Do	Pomology	do	Storage of fruits at low temperatures for preserving, canning, and soda-fountain use.
Do	Rural institutions	Economic and social	Study of economic and farming conditions in irrigated districts.
Do	Viticulture and fruit products.	Food and nutrition	Glacé fruit; miscellaneous fruit juices; grape sirup; packing dried fruit; moisture loss in dried fruit; preparation of merchantable products from surplus fruits; use of fruits in ice cream.
Colorado	Bacteriology	do	Heat-resisting bacteria in fresh and canned vegetables.
Do	Economics	Economic and social	Rural life studies
Do	Home economics	Food and nutrition	Cooking quality of Colorado potatoes. Bread-making qualities of Colorado flour.
Connecticut (State).	Analytical chemistry.	do	Analyses of diabetic foods.
Do	Biochemistry	do	Protein research and nutrition studies: (1) Proteins of green plants. (2) Relation of chemical constitution of diet to the development of rickets. (3) Studies of the relation of vitamins to nutrition. (4) Part played by proteins, carbohydrates, and fats in nutrition. (5) Effect on the eye of deficiency in fat-soluble vitamins. (6) Effect of diet on fertility. (7) Relation of chemical structure of the proteins to their nutritive value.
Connecticut (Storrs).	Agricultural economics.	Economic and social	Intensive economic studies in selected towns.
Delaware	Chemistry	Food and nutrition	Study of factors affecting jellying of fruits.
Idaho	Agricultural chemistry.	do	Iodine-content of Idaho-grown foods in relation to prevalence of goiter.
Do	Agricultural engineering.	Household equipment.	Design and installation of farm water systems.
Illinois	Animal husbandry.	Food and nutrition	The nutritive value of the proteins of feeding stuffs and the biological values of the proteins.
Do	do	do	The relation of light to nutrition (indirectly applicable).
Do	Dairy husbandry	do	Study of the preparation of fermented milk drinks and their value from a dietary and medicinal standpoint.
Indiana	Dairy	do	The manufacture, chemistry, and bacteriological study of ice cream. Study of the growth and development of rats fed with and without dairy products.
Do	Home economics	Food and nutrition and household equipment.	Studies in fuel consumption in the preparation of meals by the use of certain types of cookers.

Experiment Station projects of application to home economics, 1924—Contd.

Station	Station department conducting the research	Phase of home economics concerned	Title of project
Iowa	Agricultural economics and farm management.	Economic and social.	Farm organization studies.
Do	Animal husbandry.	Food and nutrition.	Meat investigations.
Do	Chemistry and pomology.	do	Chemical changes in the ripening and storage of apples.
Do	Dairy	do	Factors influencing the yield and consistency of ice cream.
Do	Rural sociology	Economic and social.	Farm cost of living and standard of living studies. Studies of villages and open country relationships.
Kansas	Chemistry	Food and nutrition.	Studies of the chemical aspects of certain milling processes.
Do	Milling industry	do	Chemical and milling tests on wheat produced in various agronomic experiments and comparative chemical and milling behavior of Kanred and other wheat varieties.
Do	Dairy husbandry and bacteriology.	do	Bacterial, mechanical, and temperature factors in the manufacture and storage of ice cream.
Kentucky	Chemistry	do	To determine if manganese is an essential element in animal metabolism, with particular reference to vitamins.
Do	do	do	To determine if manganese, copper, and zinc are essential factors in reproduction and metabolism.
Do	Economics	Economic and social.	Investigation of cooperative marketing and purchasing among farmers of Kentucky. The farmers' standards of living.
Michigan	Agricultural engineering.	Household equipment.	Use of electricity on the farm.
Do	Bacteriology	Food and nutrition.	Microbiology of food of man and domestic animals.
Do	do	Clothing and textiles	Flax retting.
Do	Chemistry	Food and nutrition.	Analyses of Michigan wheat and flour.
Minnesota	Agricultural biochemistry.	do	Cereal and flour investigations (transferred to flour mill). Strength of wheat flour. Chemical and biological studies in animal nutrition. (1) Factors influencing the vitamin content of milk. (2) Factors influencing the stability of vitamins in human and animal foods. (3) Studies on the chemical nature of vitamins A and B. (4) Studies on the quantitative requirements of laboratory animals for vitamins. (5) Studies regarding the function of vitamins in the animal body. Chemistry of the formation and manufacture of dairy products and factors influencing milk production and the composition and properties of milk.
Do	Agricultural economics.	Economic and social.	The organization of farmers' supply service.
Do	Agricultural engineering.	Household equipment.	Investigations of farm buildings. Heating and ventilating of homes. Utilization of electricity.

Experiment Station projects of application to home economics, 1924—Contd.

Station	Station department conducting the research	Phase of home economics concerned	Title of project
Missouri	Agricultural chemistry.	Food and nutrition	Protein storage in protoplasmic tissue.
Do	Animal husbandry.	do	Relation of diet to bodily activity and the capacity to withstand unfavorable circumstances.
Do	Dairy husbandry	do	The effect of each ingredient on the manufacture of ice cream.
Do	Home economics	do	Psychology of child nutrition. Thrice-cooked vegetables for diabetics. A nutrition problem with special reference to negro children. The effect of external temperature upon basal metabolism under usual conditions of dress. Selection and economic use of soap in the home.
Do	do	Clothing and textiles.	Color knowledge essential to costume and its practical application.
Do	Rural life	Economic and social	Analyses of the Columbia trade area showing the influence of various economic factors on shape and size of the trade area. Standard of living on the farm as factor in cost of production. Movements of rural population in Missouri. A study of the rural primary groups of Boone County.
Montana	Agronomy	Food and nutrition	Composition and quality of Montana wheats. Influence of climate upon baking quality of hard wheats.
Do	Agronomy and chemistry.	do	Changes in wheat when frosted and their effect on baking quality.
Nebraska	Dairy	do	Studies of the principles of ice cream making.
Do	Chemistry	do	Relation of certain chemical and physical chemical characteristics of Nebraska wheat to its milling and baking quality.
Do	Dairy	do	Studies of fat-soluble A as present in milk of four dairy breeds.
New York (Cornell).	Home economics	do	An experimental study of the effect of various methods of canning carrots on their antiscorbutic properties. Experiments in feeding rats, using potatoes as basis of diet. Differences in antiscorbutic properties of yellow compared with red tomatoes. Differences in vitamin A content of yellow and green beans. Studies on the keeping qualities of certain foods in household refrigerators.
Do	Rural education	Economic and social	Problems of rural school attendance. Guidance resources of rural communities. Community activities in relation to teaching.
Do	Rural social organization.	do	Village population and service agencies. Study of rural social organizations. Influence of sickness and death on the economic and social status of the family.
New York (State).	Dairying	Food and nutrition	Investigations in the manufacture of ice cream.
Do	Bacteriology	do	Tomato products investigation (cause of gaseous fermentation).
North Dakota	Milling	do	Effect of variety, soil, climatic conditions, and disease upon milling and bread value and chemical composition of wheat. Effect of storage on milling and baking quality and chemical composition of wheat. Durum wheat investigations.
Oklahoma	Not stated	Economic and social	General economic and social investigations.
Oregon	Agricultural chemistry.	Food and nutrition	Specific rôle of the inorganic elements, potassium in particular.
Do	Horticulture	do	Dehydration of fruits and vegetables. Canning of Oregon-grown apples.
Pennsylvania	Chemistry	do	Influence of commercial condensing processes on vitamin content of cow's milk.
Do	Agricultural economics.	Economic and social	Marketing survey of food products in various counties in Pennsylvania.

Experiment Station projects of application to home economics, 1924—Contd.

Station	Station department conducting the research	Phase of home economics concerned	Title of project
South Dakota	Dairy	Food and nutrition	Influence of corn silage on the vitamin C potency of milk.
Texas	Animal industry	Clothing and textiles.	Determining the grades and shrinkages of Texas wool and mohair
Do	Farm and ranch economics.	Economic and social	Survey and analysis of rural church conditions.
Utah	Human nutrition	Food and nutrition	Nutrition of infants. Relationship of breed and individuality of cows to curd characteristic of milk.
Do	Bacteriology and chemistry.	do	Changes in flour on storage.
Vermont	Animal husbandry.	do	Nutritive value of milk, its suitability for food for children and animals, conditions which affect its nutritive value, tolerance, and related questions. Work with small animals on protein and maintenance needs.
Do	Dairy husbandry	do	Acidity of ice cream mix.
Virginia	do	do	Comparison of food value of milk of different grades.
Do	Agricultural economics.	Economic and social	Production, distribution, and marketing studies of food products for Roanoke city.
Washington	Chemistry	Food and nutrition	Nutritive value of wheat and wheat products.
West Virginia	Agricultural economics.	Economic and social	Supply method of marketing and consumption of food in West Virginia cities and agricultural production in near-by territory.
Wisconsin	Agricultural bacteriology.	Food and nutrition	Factors concerned in coagulation of milk by heat.
Do	Agricultural biochemistry.	do	The effect of organic nutrients from single versus mixed plant sources on the growth and reproduction of animals. Studies of the factors necessary in the maintenance of mammals, as vitamins, light, etc. Sources of vitamins in feed; the relation of pigments to animal nutrition; the stability of vitamins and their relation to growth and reproduction.
Do	Agricultural economics.	Economic and social	Country life investigations: (1) A study of towns and villages as social and economic service stations. (2) A detailed study of 7 Wisconsin small towns. (3) Rural religious organizations.
Do	Agricultural engineering.	Household equipment.	Availability of electric power on the farm.
Wyoming	Wool	Textiles and clothing.	Studies of fleece and wool characters.

Classification of projects by departments conducting the research

Department	Number of projects	Department	Number of projects
Chemistry, including agricultural and biological	35	Bacteriology	5
Agricultural economics and rural sociology	26	Milling	5
Home economics	14	Agronomy	3
Dairy husbandry	13	Horticulture	2
Animal husbandry	8	Nutrition	2
Agricultural engineering	8	Pomology	1
Viticulture and fruit products	7	Wool	1
		Total	130

As grouped by the appropriate divisions of the subject of home economics, food and nutrition leads with 91 projects, followed by economic and social 27, household equipment 9, and clothing and textiles 4. This proportion is about what would be expected and does not differ materially from the distribution of projects in the home economics departments of the land-grant colleges. The list of projects relating to food and nutrition might well have been enlarged to include the studies on mineral metabolism which are being conducted at the various stations and are yielding results of indirect application to human nutrition. It is difficult in specific cases to draw any fixed line between animal and human nutrition. In general the principles involved are the same.

Many of the problems of agricultural economics are intimately connected with the problems of the farm home, and there is great opportunity for cooperation between the departments of agricultural and home economics. The fields of research in household equipment and in clothing and textiles are practically unexplored. In the former, cooperation with departments of agricultural engineering is desirable; in the latter, strengthening of the textile divisions in the home economics departments and cooperation with departments interested in wool and cotton. No attempt will be made here to discuss the projects classified under any of the divisions except that of food and nutrition, but it seems worth while to note the general trend of the work in this field as judged by the statements of progress accompanying many of the project lists.

GENERAL STATUS OF RESEARCH WORK IN FOOD AND NUTRITION

Food analysis.—In several of the stations the inspection of food and drugs is a part of the work of the station chemist, but as this is of the nature of routine analytical work it has not been included in this report with the exception of one project at the Connecticut State station on the analysis of diabetic foods. This is of special interest in connection with the precautions that must be taken in the control of the diet in the insulin treatment of diabetes. Of interest in this connection is the project reported by the home economics department of the Missouri station on thrice-cooked vegetables for diabetics, the purpose of which is to determine the vitamin content of the thrice-cooked vegetables which are used so extensively in diabetic diets. Preliminary work has shown that thrice-cooked spinach is entirely inadequate as a source of vitamins.

Analyses of foods for various inorganic constituents form a part of certain projects as a preliminary step to the study of more fundamental questions, such as the importance in nutrition of individual elements occurring in food materials in minute amounts. As such, may be cited the study at the Arkansas station of the iron content of certain foods, and at the Idaho station of the iodine content of Idaho-grown foods in relation to the prevalence of goiter. The latter topic is one that might well engage the attention of home economics departments of institutions in localities where goiter is at all prevalent, since the direct relation between iodine deficiency in food and drinking water and the prevalence of goiter is now an established fact. Recent surveys, conducted for the most part by public health officials, have shown that in several States, including Ohio, Michigan, and Montana, goiter is sufficiently prevalent to warrant the iodine prophylaxis of school children.

Wheat and flour studies.—At the experiment stations in the wheat-growing States chemical studies of flours milled from different varieties of wheat and from the same variety subjected to different environmental conditions, and studies of the relation of the chemical composition of the flour to its bread-making qualities are important research projects. Active investigation along these lines is being conducted by such departments as agronomy, chemistry, and milling at the Kansas, Michigan, Minnesota, Montana, Nebraska, North Dakota, and Washington stations. The scope of these studies ranges from simple chemical analyses of wheats and flours with relation to their baking quality, to physicochemical studies of the factors involved in flour strength. In so far as these investigations lead to the selection of wheat for better bread-making qualities and to the improvement of flour of poor quality by the addition of certain ingredients or the alteration of the proportions of the usual ingredients to bring about optimal baking conditions, they may rightly be considered research in home economics. There is opportunity for the home economics department and cooperate in this work and to institute similar research of their own.

Utilization and preservation of food products.—A field in which there is opportunity for close cooperation between the home economics department and other research departments is the development of methods for the utilization of perishable food products such as fruits and vegetables. At the California station the departments of pomology and of viticulture and fruit products are conducting a number of projects dealing with the preservation and utilization of surplus fruits. At the Iowa station the departments of chemistry and pomology are studying the chemical changes in the ripening and storage of apples. At the Oregon station the horticultural department lists projects on the dehydration of fruit and vegetables and the canning of Oregon-grown apples. Similar studies are contemplated by the department of horticulture at the Illinois station. In all cases one of the most important aims is to preserve as far as possible the natural flavor of the original product. To judge whether this has been accomplished and to develop the most satisfactory methods of utilizing the products, the home economics departments should be the best qualified and their cooperation should be sought by the departments conducting the research. In general, the development of better methods of utilizing food materials of all kinds is an important phase of home economics research.

There is also opportunity for cooperation between the departments of home economics and bacteriology in connection with such projects as that reported by the Colorado station on heat-resisting bacteria in fresh and canned vegetables. Wherever *Bacillus botulinus* is prevalent particular attention should be paid to the development of safe conditions of canning. The essential principles involved are bacteriological and the successful canner should be familiar with the recent important developments in bacteriology concerning thermophiles, heat penetration in various media, the H-ion concentration favorable for the growth of various microorganisms, and like questions.

Another phase of investigation along the lines of fruit utilization and preservation is illustrated by the work at the Delaware station on factors affecting the jellying of fruits. This project, under investigation by the chemistry department, deals with the relationship between acidity, pectin, and sugar concentration in the jellying of fruits. As the result of these studies and of similar work at the California station and elsewhere, jelly making is being put under scientific control and is no longer a rule of thumb procedure. The application of these principles to local conditions and to the utilization of surplus fruits suggests possible projects for home economics departments in various parts of the country.

Milk and dairy products.—Listed in the foregoing tabulation are no less than 21 projects from 16 stations dealing in some way with milk or dairy products. Six of these projects are concerned with the manufacture of ice cream and have been listed here as possibly contributing some suggestions of value in the home preparation of ice cream; two deal with the preparation of fermented milk products; several are connected with vitamin studies to be discussed later; and one or two are chemical studies undertaken primarily in connection with the manufacture of condensed, evaporated, and dried milk. Progress in all of those projects will naturally be followed closely by home economics workers with a view to possible applications.

Two of the projects listed are of particular interest as regards infant feeding. One is the Vermont station project on the nutritive value and tolerance of milk and milk preparations, in which young pigs are being used as laboratory animals to indicate the nutritive value and tolerance by children of milk of different kinds and richness and of various milk preparations. The human nutrition department of the Utah station is conducting a project with the same purpose in view—a comparison of the milk from various cows in regard to digestibility and food value for infants, but is approaching the question from a different angle. On the theory that the digestibility of milk depends largely on the softness of the curd, a curd test was developed for determining curd variance in milk, and this test has been applied to milk from different cows of the same breed and of different breeds. The results thus far obtained indicate that the curd character varies with the individual and also with the breed. Moreover, infants have responded more favorably to milk with the softer than the harder curd. This suggests an interesting application in special milk for infant feeding.

Protein investigations.—The Utah station project outlined above is essentially a protein investigation. At the Missouri station the department of agricultural chemistry is conducting an investigation on protein storage in protoplasmic tissue, the results of which may be applicable to human as well as animal nutrition. A study at the Arkansas station of the cause of the inadequacy of milk proteins for reproduction has furnished evidence of the existence of a vitamin essential for reproduction. At the Illinois station the studies of Mitchell in the department of animal nutrition on the nutritive value of the proteins of feeding stuffs has been extended to the determination of the biological values of the proteins of foods commonly used in the human diet, and results have already been reported on the relative biological values of eggs, milk, and meat as compared with wheat, oats, and corn. In the outline of the project as a whole, the statement is made that its purpose is to determine the protein requirements of farm animals and then, from the net protein values (percentage protein × percentage digestibility × biological value), the amount of different feeding stuffs required to furnish sufficient protein to meet these requirements. The further statement is made that "part of the purpose of the project is to help to define the precise value of animal products in human dietetics as compared with staple vegetable products." The application of this project to home economics is thus expressed in no uncertain terms.

At the Connecticut State station the fundamental research on proteins under the direction of Dr. T. B. Osborne is still continuing. Begun years ago as an investigation of the chemistry of plant proteins, and developed essentially as a study in animal nutrition, this work has contributed more to our present knowledge of the requirements of human nutrition than perhaps any other series of investigations. This station and the Wisconsin station through similar protein investigations have had a large share in the development of the modern vitamin conception, essentially an outcome of protein studies. In the list of projects submitted by the Connecticut station under the heading of protein research and nutrition studies, three relate specifically to proteins. The first, on the proteins of green plants, is at present in the state in which it is difficult to trace any connection with human nutrition, but the progress of this investigation should be watched with interest. A continuation of the study of the part played by proteins, carbohydrates, and fats in nutrition has emphasized the fact that "so long as the 'law of minimum' is not violated, surprisingly large variations in the quantitative make-up of the diet may apparently be tolerated." As preliminary to a further study of the relation of the chemical structure of the proteins to their nutritive value, large quantities of pure amino acids have been prepared and are being used in feeding tests. Edestin has been shown to contain no oxyglutaminic acid, and, since edestin furnishes all the amino acids needed for growth, oxyglutaminic acid has thus been added to the list of nonessential amino acids.

Vitamins.—Vitamin studies are being conducted in at least 20 of the stations. Only the projects having a direct bearing upon human nutrition are listed in the above tabulation, but in addition to these there might be cited a long list of projects dealing with the vitamin requirements of chickens, cows, and pigs. The list of vitamin projects in poultry husbandry alone numbers 20. Although many of these have no bearing upon human nutrition, others are concerned with general principles applicable alike to animal and human nutrition.

The vitamin projects listed in this survey range from simple studies of their quantitative occurrence in various food products to fundamental research on their function in the animal body. One of the most important recent discoveries concerning vitamins came from the Wisconsin station in the work of Steenbock and his associates on the activation of food materials with respect to antirachitic properties through the action of ultraviolet light. Of direct application to human nutrition is the possibility of rendering palatable foods antirachitic for use in place of the dreaded cod liver oil. The value of sunlight in supplementing the antirachitic vitamin and promoting normal mineral metabolism is already being recognized in animal feeding and should be emphasized more strongly as an important factor in child nutrition.

Another phase of the vitamin work at the experiment stations which is of fundamental importance is the relation of vitamins to successful reproduction and lactation. This problem

is being approached at the Arkansas, Connecticut State, Minnesota, and Wisconsin stations. At the Arkansas station a study of the inadequacy of milk proteins for reproduction has led to the conclusion that the failure of milk is due not to lack of amino acids but of a substance of the nature of a vitamin. This is of interest in that the results obtained confirm in practically all respects those reported from the University of California by Evans and Bishop who were the first to announce the existence of a specific vitamin for reproduction. In his work at the Arkansas station, Sure considers that he has demonstrated also that the amount of vitamin B required for the normal function of the mammary gland is greater than that for growth, thus suggesting the need of supplying an additional amount of vitamin B during the lactation period.

At the Minnesota station a project entitled "Studies on the quantitative requirements of laboratory animals for vitamins" has developed along interesting lines, including the question of reproduction. Some evidence has been obtained in support of the theory of a specific vitamin for reproduction, the vitamin X of Evans and Bishop or E of Sure, but it is the opinion at the Minnesota station that both yeast and milk contain this vitamin. In addition evidence has been obtained pointing to the presence in cow's milk of another factor promoting lactation. This appears to be distinct from the other known vitamins. Evidence has also been obtained that still another factor is essential for normal physical well-being and possibly for growth. The lack of this factor in the diet of rats is followed by a peculiar greasy appearance of the fur. The condition may be cured or prevented by feeding small quantities of milk, protein-free milk, commercial lactose, and the like.

A practical vitamin project relating to milk is the study at the Nebraska station of the fat-soluble vitamin A content of the milk of different dairy breeds. One cubic centimeter daily of Jersey milk has proved sufficient to restore weight and health and check ophthalmia in rats on a ration deficient in vitamin A, but this quantity is not sufficient with Holstein milk.

These studies are cited not so much for the purpose of serving as a progress report on vitamin work at the stations as to illustrate the type of research which may be considered fundamental as compared with tests for vitamin occurrence (at least when not concerned with the discovery of principles governing such occurrence). Vitamin studies are still in their infancy and there are many problems which may very properly be investigated by home economics departments. One problem on which only a beginning has been made is the stability of the various vitamins during cooking and canning processes. One of the projects reported by the home economics department at the New York Cornell station, "An experimental study of the effect of various methods of canning carrots on their antiscorbutic properties," illustrates this type of vitamin research.

Mineral metabolism.—Closely bound up with studies dealing with the fat-soluble antirachitic vitamin are studies on mineral metabolism, particularly that of calcium and phosphorus. A review of the station work up to and including 1922 on fat-soluble vitamins, particularly in relation to mineral metabolism, was given in a previous report[5]. Many of the stations, including those of Iowa, Kansas, Michigan, Ohio, Oregon, and Wisconsin, are still engaged in such studies. As most of the projects at present listed in this connection deal with the nutrition of farm animals, they have not been included in the present survey, although undoubtedly of indirect application. In the same class might be considered studies at the Oregon and Washington stations on the significance of potassium and sodium in animal nutrition and at the Montana, North Dakota, and Wisconsin stations on the relation of iodine to animal nutrition. The study at the Kentucky station of the significance of manganese, copper, and zinc in reproduction and metabolism has been included in the present survey as possibly of more direct bearing upon human nutrition.

GENERAL OUTLOOK FOR HOME ECONOMICS RESEARCH AT THE EXPERIMENT STATIONS

Considering home economics research as an integral part of the work of the experiment stations, its present status, at least in the division of food and nutrition, is encouraging. Well-established lines of research in several departments are contributing funda-

[5] U. S. Dept. Agr., Off. Expt. Stas., Work and Expend. Agr. Expt. Stas., 1922, p. 79.

mental knowledge of application to human nutrition. With the development of research the home economics departments will be in position not only to carry on independent investigations but also to supplement materially the work of other departments by cooperative investigations along the lines indicated above, and others which will suggest themselves in connection with the individual problems confronting the various stations.

BREEDING WORK WITH FIELD CROPS AT THE EXPERIMENT STATIONS

By Henry M. Steece, *Specialist in Agronomy*

Breeding work with field crops at the State experiment stations has produced important practical results in crop improvement and has contributed much information of value concerning the principles of genetics and the refinement of technique. During the last 20 years, the application of Mendel's laws of heredity to crop plants and the use of improved methods of selection and pure line breeding have received much attention at the stations and have been very fruitful in results. This work supplements the highly valuable investigations of other American and foreign workers and of the United States Department of Agriculture. In the following pages attention is called to some of the inheritance studies carried on with the principal field crops, the relation of the mode of reproduction to crop breeding, and examples of the results of selection work and breeding for special adaptation.

INHERITANCE STUDIES WITH THE MAJOR FIELD CROPS

Corn.—Corn is the most important crop in the United States, and consequently the problems involved in its production and improvement have been investigated extensively at the experiment stations. The many efforts made to enhance yielding power and to produce uniform seed types have quite logically led to inquiry into the inheritance and interrelations of the factors concerned with yields and seed character. Inheritance of row character was evident at the New Jersey stations (145)[6] to the extent that the larger the number of rows in the parent ear the greater was the tendency to produce many-rowed and zigzag ears. The proportion of zigzag ears was greatest when taken from a zigzag parent ear. In studies made at the New York Cornell station (169) on the progenies of corn plants having wholly pistillate inflorescences, one a type called tassel seed and apparently entirely distinct from another type known as tassel ear, the two characters were shown to be linked and recessive.

Starchiness of kernel was found in studies at the Connecticut State station (23) and Bussey Institution to be a separate plant character independent of the physical form in which it exists. The characters giving the flint or dent appearance to corn seemed to be transmitted to the entire ear and not as endosperm characters to the individual seed. They showed segregation, and were held due to the action of more than one transmissible character. The podded character of pod corn was found to behave as a simple Mendelian dominant. A tendency for connate seed to be inherited was noted at the Virginia station (215). Continuously growing sporophytes observed in strains of corn at the Missouri station (127, 128) were due to two distinct factors inherited as simple recessives.

The inheritance of certain endosperm differences of various races of corn that have been made the basis of a division into the subspecies *Zea mays everta*, *indurata*, *indentata*, and *amylacea* and of the shape of seed characterizing the so-called rice pop corns was investigated at the Connecticut State station (25). Regardless of the variety used as the female parent, no immediate visible effect of the male parent appeared in the endosperm of crosses between flint and floury corn, and a cross between the floury and Leaming dent behaved similarly. In plants having fundamentally the same zygotic possibilities as regards the type of starch in the endosperm, the amount of soft starch actually developed is directly proportional to the size of seed. Pollen of White Rice pop corn apparently had no effect on the character of the endosperm of the floury type. The character for floury endosperm appeared to be recessive to that for flintiness at the New Jersey stations (146) and the form of flintiness classed as an ear or plant character was not read-

[6] Numbers in parentheses refer to references, p. 54.

ily transmitted through cross pollination to adjacent pure sweet grains (144). Linkage involving aleurone, endosperm, and chlorophyll factors has been investigated at the New York Cornell station (159, 162, 164, 166).

Defective seeds, heritable corn variations in which the endosperm is lacking or is incomplete or abnormal in its development, have appeared in all the so-called subspecies of corn with the possible exception of *Zea mays tunicata* and in more than 30 representative American varieties, as well as in several varieties from Spain and one from Peru. Genetic studies at the Connecticut State station (35) gave evidence that many different factors are involved which may cause defective seeds in corn. Scarred endosperm was shown at the Missouri station (126) to be inherited as a simple Mendelian recessive. Correlated with scarred endosperm was a difference in size of kernel apparently due to the same factor. An endosperm defect in sweet corn termed "sweet defective" (63) and another character known as miniature germ (64) were inherited as simple Mendelian recessives, at Iowa State college. The inheritance of a defective endosperm at the West Virginia station (228) seemed to be controlled by a single factor difference.

The inheritance of color in the different organs of the corn plant has been given considerable attention. An absolute, presumably genetic, correlation was apparent between color of cobs, pericarp, husks, silks, and anthers at the Nebraska station (136). A somatic variation concerned with the development of a dark red or brown pigment in the pericarp of the grains, often associated with an apparently similar pigment in the cob and husks, was shown (134) to be a simple Mendelian in inheritance. Purple aleurone color behaved as a normal Mendelian character at the Connecticut station (23). Studies involving the factors influencing the development of the various red sap colors appearing in the pericarp, the cob, the husks, the silks, the glumes, and the anthers showed that coupling sometimes occurred, but as a rule independent of the red in the other parts of the plant. A study made at the Connecticut and Minnesota stations (105) of the relation of various pericarp characters in crosses between the various homozygous types, suggested that certain combinations produce germinal instability, and led to conclusions that the factors for self-red, variegated, pattern, and colorless pericarp form a series of multiple allelomorphs.

From studies of the various categories at the Nebraska station (142) it appeared that in practically all cases the several types of albinism in corn leaves behave as simple Mendelian recessives. The inheritance of eight chlorophyll types was found to be strictly Mendelian and all were recessive to normal green at the New York Cornell station (154). Salmon and brown silks were shown at this station (157) to be recessive to green silks by a single factor pair. An exhaustive investigation at this station (156) dealt with the genetic and environmental relations of six major plant colors of corn—purple, sun-red, dilute purple, dilute sun-red, brown, and green (colorless), together with the subtypes—weak purple, weak sun-red, green-anthered purple, green-anthered sun-red, and five genotypes of green.

The relative size of plants was not transmitted to any degree at the Nebraska station (137) and variation in size of plant was considered due to some local cause rather than inherited. Further observations at that station (133) suggested that length of ear is directly correlated with height of plant and inversely correlated with number of rows per ear. Number of rows seems also to be related to the character of the endosperm. The interrelations of such characters as number of rows per ear, circumference of ear, and breadth of seeds are obvious. Absence of ligule and auricle seemed to be recessive at the Nebraska station (138) and independent of several common characters in corn in inheritance. A genetic analysis at the Missouri station (124) indicated that two factors were concerned in the inheritance of zigzag culms, such culms appearing only when both were recessive. Biometrical studies at the Virginia station (214) had to do with the ear and plant characters of corn, the inheritance of certain characters as influenced by hybridization, and inheritance of correlated characters.

Although numerous corn breeders and investigators have long sought for some character of the corn plant which could serve as an index to potential yields, correlation studies with corn failed to reveal plant or ear characters that were significantly related to yielding ability at the Nebraska (137), New York Cornell (149), Kansas (70, 72), Missouri (125), and Ohio (183) stations. The average circumference of the seed ear

was the only character showing any significant relation to yield at Cornell University (165). Continued selection at the Illinois station (52) apparently induced a certain correlation between the protein and oil content in corn and resulted in characteristic types of kernel and perceptible modifications in the type of ear. Selection for high protein was evidently accompanied by a reduction in yield. Height of ear and yield were to some extent positively correlated at the South Dakota station (202), the higher growing ears indicating heavier yielding strains of corn, however, later in maturing than the low-eared corn. It seemed at the Virginia station (216), that points emphasized in the corn score card may be of value in selecting high-yielding strains, and that high-yielding strains are high-scoring strains. According to other results at this station (218), ears which germinate early produce plants which ripen late, and the plants which tassel and silk early mature late and yield high.

Wheat.—The principal aim of wheat improvement is the production of high yielding varieties, but milling and baking quality and resistance to drought and disease are also important considerations. Through selection and hybridization, many of the experiment stations are engaged in breeding new varieties and improving existing types of wheat. Data accumulated during recent years on the inheritance of unit characters in wheat tend to show that the process of fixing new hybrids may be simplified, that the breeder may predict with a fair degree of assurance what combinations of unit characters may be associated and fixed in a new variety, and that new varieties having desired attributes and qualities may be bred with certainty.

From observations at the South Dakota station (201) the length of the central spike of wheat can not be considered as the indicator of the fitness of a given plant to serve as the mother of a line of progeny. Detailed study of the different modes of inheritance in crosses between *Triticum spelta* and *T. sativum* has been carried on at Cornell University (170) in cooperation with the United States Department of Agriculture. Squareheadedness, the result of a combination of growth characters, showed a complex mode of inheritance at the New York Cornell station (158) and was correlated to a certain extent with width of culms. Density was found dominant over laxness, and density and the shortening of the other length characters appeared to be the result of a single dwarfing factor. Further investigations (173) seemed to show that the spelt factor decidedly interferes with the full expression of the factors for density and those for squareheadedness. In studies of the inheritance of seed and spike characters in wheat crosses at the Minnesota station (99) indications were that length of seed is inherited similarly to other size characters; that the awn of wheat is apparently an important physiological organ; and that awned varieties may be expected to yield somewhat better than awnless wheat. A genetic linkage was apparent at the Arizona station (6) between one or more of the factors controlling the grain texture and head shape in the varieties of macaroni and bread wheat used as parents.

The genetic behavior of true softness in wheat may be explained by two independent factors which govern the relative proportion of gluten and starch, according to inheritance studies at the Arizona station (8). The genetic factors governing the appearance of yellow berry are evidently distinct from those producing true softness and are said to be very sensitive to environic influences. Genetic factors for sensitivity appeared to be inherited as definitely as are other factors governing quantitative characters. From the work at this station (7), the gradual softening of an impure race of wheat might be explained as climatic selection without the necessity of assuming any direct or accumulative influence of the climate upon the hereditary substance itself. Percentage of plumpness of seed was said to be an inherited character at the Minnesota station (116) and associated with high average yield per plant. Some strains produce a higher proportion of yellow-berry kernels than others, and in some cases this tendency is inherited.

Growth habit characters segregated in accordance with Mendelian laws in the progeny from Kanred×Marquis in Minnesota (119), the presence of multiple factors being indicated. In both direct and reciprocal crosses between true spring and true winter wheats at the New York Cornell station (172) the short vegetative period was dominant. Apparently a dominant factor for winter and an inhibitor against winter were involved. High tillering mother plants tended to produce a larger proportion of plants

with more tillers than the average at the Delaware station (36), but the inheritance of tillering as indicated by the performance of individual plants was not marked. When crossed with certain other normal varieties of wheat at the Washington station (223), Marquis, Baart, and Kubanka all produced a certain percentage of dwarf plants. Dwarfness seemed to be associated with late ripening and was possibly linked in some degree to winter habit. Dwarfness in wheat at the North Dakota station (181) was accompanied by unexpected ratios in segregation.

Correlation studies at the Delaware station (38) indicated that the number of sterile spikelets is likely to increase with the length of the wheat spike, whereas cytological studies at the Minnesota station (101) failed to show correlation between morphological and botanical head characters and sterility in wheat. The immediate progeny of Marquis wheat appeared to make higher yields from long spikes than from relatively short spikes at the South Dakota station (203), but this correlation did not seem to persist.

The relationships existing between crude protein, dry gluten, gliadin, water absorption, flour yield, and loaf volume for the wheats found in different parts of the country have been compared at the Maine station (84). Correlations between protein content and crushing or breaking point of the kernel, specific gravity, and volume of the grain were either very slight or nil in studies at the Kansas station (73). Wheat kernel plumpness was not found to be correlated significantly with crude protein (or crude gluten) content at the Minnesota station (117).

Oats.—The possibilities of improving the oats crop by the selection of good plants from a variety or by combining through hybridization the desirable qualities of different varieties have been shown at Cornell University (163). The inheritance of certain glume characters in the cross *Avena fatua* × *A. sativa* have been reported in detail from the Maine station (87). Crosses between hulled and naked types of oats at Cornell University (167) and at the Maine station (88) segregated in a ratio of 1 hulled, 2 intermediate, 1 naked. A nearly complete dominance of the awnless condition was observed in a cross between the fully awned Burt and the awnless Sixty Day types at the New York Cornell station (155). Both parents seemed to contain the factor for awning, but this was prevented from operating in Sixty Day oats by an inhibitor closely linked with the factor for yellow color in that variety. Strong linkage was noted between the fully awned condition and the medium long hairs at the base of the grain and the Burt type of basal articulation. Extensive investigations at this station (151, 152, 153) in cooperation with the United States Department of Agriculture were made to determine characters in the oats plant which could be used as bases for selection and to determine the status of correlation of characters in oats.

A study of *Avena sterilis* × *A. orientalis* at the Washington station (226) showed that resistance to smut was completely dominant and apparently caused by multiple factors. The black color of the floral glume of *A. orientalis* behaved as a simple dominant, while the shape of the panicle was probably determined by multiple factors. When crossed with white hulled varieties at this station (221), one variety of white hull-less oats produced black oats. Hull-lessness prevented the development of glume color in the parent and hybrids of all the crosses tested. The behavior of oats hybrids at the Minnesota station (97) showed that rust resistance is inherited as a dominant character depending on a single factor difference for its expression, and panicle type apparently depends on a single main factor for expression. Neither character seemed to be closely linked in inheritance.

Barley.—That crossing, even though taking longer, will prove better than selection for the ultimate improvement of barley was indicated by nursery results at the Minnesota station (95). However, the value of the pure-line method of breeding was not disputed. Hooded barley was dominant over bearded, covered over bald, and 2-row over 6-row at the Washington station (221). The characters were produced by multiple factors or were irregular in inheritance. The Minnesota station concluded from investigations made in cooperation with the United States Department of Agriculture (104) that internode length in the barley rachis is a very stable character, much less affected by environmental conditions than many size characters. The occurrence of *Hordeum intermedium* and other segregates in the progeny of a cross of

Manchuria and Svanhals barleys has been described from results obtained in similar cooperation (111). The linkage or independent assortment of a number of genetic factors in barley has been studied at the University of California (19).

Cotton.—Improvement of cereals has been an outstanding phase of plant breeding work in this country, but the other field crops have by no means been neglected. The southern stations, notably Arkansas, Alabama, Mississippi, North Carolina, Oklahoma, South Carolina, and Texas, have worked with new or improved strains of cotton which promise better yields and quality of lint, and genetic studies with this crop are beginning to show results. The heritable characters in cotton crosses observed at the Georgia station (46) seemed to obey Mendel's law of dominance, segregation, and recombination. Observations on different varieties of cotton at Georgia State College (47) indicated that the marked differences which exist between varieties in the oil content of the seed remain fairly constant, and are transmitted from generation to generation. High and low oil contents in cottonseed were maintained during several generations at the Texas station (206). Other aspects of breeding work with cotton are discussed under succeeding topics.

Potatoes.—Expansion of the potato industry in the United States has created demands on the plant breeder for varieties adapted to certain regions or environmental conditions, possessing specific qualities, and resisting diseases. A few of the results of genetic and correlation studies made in response to these demands will be described briefly here, and selection work with potatoes will be discussed later.

By stimulating seed production through prevention of tuber formation by removing the earth from around the stolon, in experiments at the Connecticut State station (28), characteristic differences in seeding power were found which are inherited by different varieties. Although the large variations in these characters could be increased artificially by changing environmental conditions, no ordinary treatment would force a variety across its critical point into another biotype. According to results at the Minnesota station (115), tuber shape depends essentially on the presence or absence of a single factor for length. Both early and late-maturing seedlings were obtained in F_2. Although the heterozygous condition of the parent varieties complicates matters, it does not appear to prevent the combining of the desirable characters of the parent varieties into a commercial variety, if large enough populations can be grown.

Only those correlations where color was manifested in different parts of the plant exceeded the probable error in a study of correlations between potato characters at the Connecticut State station (28). In the fall crop of Lookout Mountain potatoes at the South Carolina station (198), vegetative growth was highly correlated with seed production and with yield of tubers, while a lesser degree of correlation was found between seed production and tuber yield, apparently indicating that conditions favoring one character also favor the others and that no mutual antagonism exists between the several characters rather than an inherent connection between the characters. No relation seemed to exist between the yield of marketable tubers and the tuber characters of Green Mountain potatoes at the Virginia station (217). However, the yield of marketable tubers had a high positive correlation with the number of tubers produced and a significant negative correlation with the yield of nonmarketable tubers. Other correlations were recorded between tuber characters at this station and at the Minnesota station (118). Shallowness of eye was found by the Montana station (131) to be correlated with degeneracy.

Sorghum and sugar cane.—Although the improvement of the sorghums has been largely achieved by selection, several characters have been subjected to genetic analysis. In crosses between dwarf milo and feterita studied by the United States Department of Agriculture partly in cooperation with the Texas station (209), the awn was found to be recessive, and the broad truncated shape of the awned milo glumes were dominant over the narrower ovate shape of the awnless feterita glumes. When Red Amber sorgo was used as the pistillate parent in several crosses, the red in its glumes was found dominant over the black in glumes of feterita, with only a single factor difference between red and black glumes. The uniformly red-brown seed color of Red Amber sorgo was dominant over the bluish-white seed color of feterita,

with two independent unit factors apparently involved in the determination of seed color.

No evidence of the transmission of an abnormal spur at the base of the kafir head to the progeny was obtained at the Lubbock, Tex., substation (207). In hybrids between Blackhull kafir and Red kafir, the Red kafir type and shape of head was dominant, while the seed color was intermediate. According to other studies at this substation (210) the so-called varieties of milo and of kafir seem to differ from one another in seed coat color by a single factor, whereas different classes or groups of sorghum, such as feterita and kafir or feterita and Red Amber, differ by two or more factors affecting seed coat color. The lack of hybrid vigor in any of the crosses of milo on milo or kafir on kafir and the extraordinary heterosis shown in the F_1 generation of crosses between classes or groups of sorghum further indicates more genetic differences between classes or groups than exist between the different forms of milo or kafir.

Seedling sugar canes in the F_1 generation in Porto Rico (196) somewhat resembled the parent varieties of sugar cane, particularly as to color. Seedlings showed wider variations than canes produced from cuttings of the same variety. New types of cane were obtained by crossing different varieties, variation appearing to be increased by such combination.

Soy beans and velvet beans.—The inheritance of characters in soy beans has been studied to a rather limited extent. Dark colored and light colored pods in soy beans studied at Wisconsin station (238) constituted an allelomorphic pair of characters, dark being dominant to light and differing from it by a single factor pair. Purple (colored) and white flower color (recessive) constitute a simple Mendelian pair of characters. Perfect correlation apparently exists between flower color and stem color, such that purple flowers always accompany purple stems, and white flowers, green stems. In the progeny of a cross with black Venezuelan beans at the Porto Rico station (193), blackness of the seed coat was found to be dominant over whiteness and glossiness over dullness. The genetic relations of some of the characters of the velvet bean have been investigated at the Florida station (39, 40, 41, 42, 43, 44). In this work the Florida velvet bean (*Stizolobium deeringianum*) was crossed extensively with the Lyon bean (*S. niveum*) and also with the Yokohama and China velvet beans.

Tobacco.—Breeding work with the tobacco plant not only has its economic aspects, but the tobacco genus Nicotiana is considered especially favorable material in the study of plant genetics. Extensive experiments with tobacco at the Connecticut State station (24) produced results in accord with the hypothesis that the inheritance of quantitative characters, such as size, shape, and number of various plant organs, may be due to the interaction of a multiplicity of factors, each inherited separately and capable of adding to the character. From the plant breeding standpoint there seemed good reason for believing that quantitative characters are inherited in the same manner as qualitative characters. The branching or suckering habit of tobacco appeared to be a distinct characteristic and to behave as other inherited characters at the Wisconsin station (235), although subject to considerable variation, because of environmental and physiological factors. The inheritance of this habit is regarded as purely quantitative and not separable into satisfactory classes or ratios.

Crossing certain varieties of *Nicotiana tabacum* at the California station (13) demonstrated the complexity of difference from a genetic standpoint between any two of the so-called fundamental varieties of *N. tabacum*, and showed the futility of seeking to determine affinities on the basis of morphological studies unaccompanied by experimental investigations. The genetic studies led to the conclusion that all *N. tabacum* varieties must be regarded as fundamentally equivalent from a genetic standpoint. In addition to these crosses (14), a series of papers on inheritance in *N. tabacum*, reporting investigations at the California station, were also concerned with the existence of genetically distinct red-flowering varieties (15), the occurrence of two natural periclinal chimeras (16), the trisomic character "enlarged" (17), and the occurrence of haploid plants in interspecific progenies (18).

RELATION OF THE MODE OF REPRODUCTION TO CROP BREEDING

The breeding work and genetic studies at the stations have produced much information in regard to the effects of inbreeding, hybridization, natural cross pollination, the causes of hybrid vigor and sterility, and the behavior of mutations.

Pollination.—Pollination studies have shown differences in seed production and the existence of self-fertile lines in red clover in Kentucky (74), self-fertility in vetch in Oregon (185), the deleterious effects of selfing corn in Nebraska (140) and in Minnesota (106), and self-sterility in sunflowers in Montana (129). Failure to get potato seed may be due to hereditary sterility of the pollen, unfavorable environmental conditions, and the shedding of the blossoms, which is probably the manifestation of the first two causes, according to studies at the South Carolina station (198). Self-fertilized clonal lines of timothy studied at the Minnesota station (114) varied widely in the quantity of seed set, probably due to genetic causes.

Inbreeding.—The effects of inbreeding of normally crossed fertilized crops have been studied most extensively in corn. Adverse results followed inbreeding of corn at the Nebraska (139), Mississippi (122), Pennsylvania (186), and Wisconsin (234) stations in contrast to the favorable showing made under open pollination or by hybridization. By the use of indices related to enzymatic activity, highly inbred corn that in some cases equaled crossbred corn in vigor, was obtained at the Delaware station (37). The varieties sustaining inbreeding best at the Mississippi station were usually those yielding well in other tests. Inbreeding kafir at the Texas station (211) did not cause a reduction or increase in the size of the head or in productivity, except in so far as it has isolated subvarieties differing from the parent family.

Hybrid vigor, as exhibited in crosses between varieties of corn, has been considered responsible for increased yields or resistance to adverse environmental conditions at the New Jersey (143), Connecticut (27, 30), North Dakota (180), Kansas (69), Nebraska (139), and Virginia (213) stations. On the other hand only slight or unprofitable increases were obtained at the Mississippi (122), Pennsylvania (186), and Minnesota (96a) stations. The only type of F_1 varietal cross proving of much value in Minnesota was the hybrid between an early flint and a later dent which appeared of promise for northern Minnesota. If selection to ear type is not closely followed, it is concluded that the use of F_1 crosses between standard varieties will not lead to a material increase in yield. Results at the Connecticut stations (31) and elsewhere supported the assumption that hybrid vigor results from assembling the greatest number of favorable growth factors and not from an indefinite physiological stimulation. Crosses between varieties of diverse type therefore possess more favorable growth factors than crosses between similar varieties, and hence give larger increases when crossed. Hybrids between selected self-fertilized lines of corn have outyielded the highest producing varieties grown at the Connecticut State station (27). Likewise at the Nebraska station (141) hybridization of self-fertilized lines seemed to be the most promising method of corn improvement.

Crossing normally self-fertilized crops.—Natural hybridization or vicinism is of the greatest interest from the viewpoint of normally self-fertilized crops. Limited experiments at the Georgia station showed that natural crossing occurs in cotton (46). While rather low percentages of natural hybrids in cotton resulted at the Mississippi station (121), varietal differences were apparent. Only a few of the ovules seem to be affected in the natural crossing of a flower. Preliminary observations at the Texas station indicated that an average of 6 per cent of natural cross-fertilization occurred in white milo plants mechanically introduced into a plat of yellow milo (208). Natural cross-pollination in grain sorghums averaging 1.67 per cent was also noted at Lubbock, Tex. (207). Natural hybrids were so numerous in soy bean varietal plats at the Indiana station that artificial hybridization was not thought necessary to produce new sorts (60). According to observations at the Wisconsin station (237), if all ways in which crossing may occur in soy beans are considered the proportion would be 1 hybrid pod in 625, or 0.16 per cent. The percentage may presumably differ with the variety, the locality, and the season.

The observed crossing in lines of *Triticum vulgare* amounted to 1.3 per cent at the Minnesota station (107), and assuming that it occurred as often within the variety as between different sorts natural crossing in 1917 probably ranged from 2 to 3 per cent. The appearance of F_1 plants in supposedly pure lines of wheat is thought to have led to the belief that hybrids frequently revert to type. The results obtained in experiments at this station and at Arlington, Va. (109), showed the necessity of protecting

emasculated flowers from undesired pollination in studies of inheritance in wheat hybrids and in breeding operations where hybrids of known parentage are desired. Natural crossing in wheat has also been reported on from the West Virginia station (227).

Examples of hybrid vigor observed in normally self-fertilized species may be cited. F_1 hybrids of certain pure lines of cotton proved earlier, more vigorous, and more productive than either parent at the North Carolina station (176). Seedlings from hybrid sugar cane seed appeared to grow stronger and with greater vigor at the Porto Rico insular station (195) than those from uncrossed seeds. The lack of hybrid vigor in any of the crosses of milo on milo or kafir on kafir employed in studies at the Texas station (210) would indicate a close relationship between the milos and between the kafirs, especially in growth factors. Where the phenomenon was distinct at Iowa State College (65) practically all the indications of heterosis in F_1 hybrids between soy bean varieties were made within the three weeks prior to cessation of growth. In yields per plant, the percentage increases of the hybrids over the parents ranged from 59.6 to 394.4. One of the immediate effects of cross-pollination, noted in studies at the Minnesota station (113) of the increased vigor of F_1 crosses between species and varieties of Triticum, was an increase in seed weight in all varietal crosses. In all varietal crosses the F_1 hybrid surpassed the parental average in yield of grain per plant.

Sterility.—Evidence of the inheritance of sterility in corn was obtained at the New Jersey stations (147) and the South Carolina station (199). At the latter station barrenness was apparently correlated with such characters as color, size, and shape of plant, and length of life.

Varieties of wheat grown under field conditions at the Delaware station (38) exhibited a higher percentage of sterile spikelets than where the plants were spaced 6 inches apart, as in the centgener method. Sterile spikelets were more profuse in the awned varieties than in the awnless and in the earlier plantings as compared with later seedings. The number of sterile spikelets appeared likely to increase with the length of the spike. The F_1 generation of crosses of emmer or Mindum with varieties of *Triticum vulgare* or with Little Club showed a high degree of sterility at the Minnesota station (113). The Maine station reports (83) that the wheat varieties in the einkorn group are interfertile but are sterile or only slightly fertile with the emmer and vulgare groups. The species and varieties of the emmer group are interfertile but are partially sterile with the vulgare group which are also interfertile. The size of the pollen grains appears to vary in different species of Triticum, and seems to be closely correlated with the sterility relationships of the three groups mentioned above, although it is said to have little or no effect on the percentage of grain set in crossings. A high proportion (85) of abnormal pollen grains was noted in the F_1 of crosses between the groups bearing 7 and 14, and 14 and 21 genetic chromosomes. Although crosses between wheats differing in chromosome number may result in small, wrinkled grain and more or less sterility in the F_1 generation, little or no correlation was found by the Maine station (86) between F_2 endosperm development and F_2 sterility or vegetative development.

A study of hybrids of several species of Stizolobium at the Florida station (45) suggested that the degree of sterility of some hybrid plants may be determined accurately by microscopic examination of the pollen of healthy flowers and sections of the ovules. The random abortion of half the pollen grains and half the embryo sacs is apparently due to the segregation of Mendelian factors and not to the action of these factors on the zygotes. Timothy was found to be highly self-sterile under conditions at the Minnesota station (99).

Bud variations and mutations.—Apparent mutations have been found in the course of breeding work at several stations and their characteristics have been studied. The behavior of variations in the potato reproduced by budding at the Connecticut State station (29) appeared to be in many ways essentially like that of variations coming from seed. Practically all of the variations found concerned characters that Mendelize in sexual reproduction. Since no changes of commercial value have been found, asexual selection could hardly be recommended as a commercial means of actual improvement. An eversporting type of buckwheat was studied at the Maine station (81). Blotch leaf of corn, inherited as a recessive, or nearly recessive, character is believed at the

New York Cornell station (161) to have originated as a somatic mutation in a single plant. The development of two flowers in the corn spikelet is considered by this station (160) to be a reversion toward a more primitive many-flowered condition. Bud variations in tobacco have been observed at the California station (10) and Connecticut State station (33). Bud selection experiments with sugar cane at the Porto Rico station (194) gave negative results.

CYTOLOGY

The cytological work that has been reported for the more common crop plants has been described as limited and fragmentary. In an effort to meet the need of students and practical plant breeders for such information, a cytological study of the pistillate spikelet and flower of the corn plant was made at the Kansas station (70a). The chlorophyll types of corn were studied at Cornell University (171) to determine if any visible structural differences in the cells could be responsible for or correlated with the known genetic behavior of these plants.

That einkorn possesses 7 haploid chromosomes; the emmer group, consisting of *Triticum dicoccum*, *T. durum*, *T. turgidum*, and *T. polonicum*, has 14 haploid chromosomes; and the vulgare group, consisting of *T. vulgare* and *T. compactum*, has 21 haploid chromosomes, was shown in cytological investigations at the Maine station (89). The chromosome behavior in partially sterile hybrids between different species of the foregoing groups has also been the subject of extensive study (85). The sterility, genetics, and cytology of a number of wheat species crosses were studied cooperatively by the Maine and Washington stations (90). Cytological studies in wheat at the Minnesota station (101) failed to show a correlation between morphological and botanical head characters and sterility. The development of the microspore and male gametophyte and of the megaspore and female gametophyte of wheat, fertilization and early embryonic development, and endosperm development have been given attention at the Washington station (222).

SELECTION

The aim of selection is to isolate the types of plant which most closely approach the ideal and to choose systematically from the produce of these types the variations most likely to be of economic value. The extent and characteristics of numerous variations of more or less significance in improvement work have been studied in brome grass at the Colorado (20) and North Dakota (178) stations, buckwheat in Maine (81), corn in Illinois (51) and Maine (78), kafir in Texas (205), peas in Massachusetts (92), oats in Maine (77), sunflowers in California (12), timothy in New York (148, 150), tobacco in Connecticut and Massachusetts (32), and in California (11), and wheat in Ohio (184).

Selection has improved the ability of alfalfa to produce seed at the Colorado station (21), altered plant characters in corn in Guam (48), and raised and lowered the oil and protein contents, position of the ear, and yields of corn at the Illinois station (52, 53, 55). Score card selection of corn seemed without practical value at the Minnesota station (96) and apparently would reduce yields if continued long without introduction of new blood. Ear type selections with corn appeared at the Nebraska station (135) to indirectly result in a selection of the correlated plant characteristics, which differ in their adaptation to various environmental conditions. Type of cotton plant could not be considered as an index to the potential productivity at the Arkansas station (9).

Selection within pure lines of oats was without effect at the Michigan (94) and Maine (79) stations. In all cases at the latter station (80) the average yield of the pure lines selected from a given variety of oats exceeded the yield of the parent variety. Among oats selections which have proved their practical value may be mentioned Iowa 103, Iowa 105, and Iowar, all of which are pure-line selections from Kherson, made at the Iowa station (62).

In the case of the potato, according to Stuart (239), selection implies the isolation and asexual propagation of desirable strains or types. The limitations of selection are those found within the varieties themselves. In line selection work with potatoes at the Montana station (132), selection based on vine development alone promised to be more reliable and practical than selection based on tuber production either by weight or number. Since a close correlation is indicated between top characters and productivity, selection based on top char-

acters is deemed not only safer but easier than bin selection (130).

Efforts made at the Minnesota station (110) to select strains resistant to degeneration ended in failure. High and low-yielding hills and tubers possessing so-called desirable and undesirable characters followed the same course, low-yielding hills often giving the better results. No difference was found in Minnesota (100) in the yield or form of tubers between lots of Early Ohio potatoes obtained from growers who had practiced continuous selection in the same seed stock for 20 years or more and those from growers practicing little or no selection. Potato varieties apparently do not run into definite strains and are relatively stable under vegetative propagation, according to results at the Minnesota station (118). The method of asexual selection did not seem to offer reasonable hope for their further improvement. Selecting eight different types of White McCormick for three years at the Maryland station (91) failed to give an increase of the desired types. In tests at the Utah station (212) concerning the power of a strain of potatoes to transmit its desirable qualities to succeeding generations, selected strains were superior in growth and yield factors to unselected potatoes of the same variety.

High-line and low-line strains in soy beans have been isolated at the Wisconsin station (233) in selecting for increased oil content, but the quality of oil was not changed. A definite relation was noted between plant height and quality of oil. Both high and low producing strains were isolated (232). Strains of soy beans producing higher percentages of oil were obtained at the North Carolina station (175), but they were the poorest yielders, and the largest quantity of oil per acre came from those strains yielding the most seed. Selection has also produced sugar canes with high sugar contents at the Louisiana (75) and Virgin Islands (219) stations, richer sugar beets in South Dakota (200), and improved varieties of timothy in New York (150), Pennsylvania (188), and Minnesota (99). Improved types of tobacco also were obtained in Wisconsin (229), Pennsylvania (187), and Connecticut (26).

Under the same environmental conditions in Maine (82), pure lines of wheat showed distinct differences in physical and chemical characteristics and in the bread value of their grain. In experiments at the Washington station (220), high or low nitrogen content did not seem to be a property of wheat which can be fixed by line selection.

BREEDING FOR SPECIAL ADAPTATIONS

Droughts, unfavorable environment, insects, and diseases have always hindered crop production and constantly serve to stimulate the efforts of plant breeders. Some degree of success has been attained by the introduction or breeding of strains resistant to one or more of these factors, and investigations in progress are very promising.

Drought resistance.—Differences in the relative drought resistance of pure races of alfalfa were seen at the Kansas station (66) and several hybrid strains of corn showed superior drought resistance (67). That varieties of alfalfa differ markedly in their ability to become more or less dormant during seasons of extreme heat or water famine was observed at the Arizona station (3). Breeding experiments at this station (4) have produced a hardy and drought and heat resistant variety of sweet corn from a few grains originally found among the native corn grown by the Papago Indians. Certain strains of Turkey wheat, all of which were hard when grown in the Central Plains States, immediately became soft when grown in Arizona (5) under irrigation, whereas other strains from the same sources have remained hard and retained their ability to produce high yields. Some tobacco hybrids produced in Ohio (182) exhibited great drought resistance and others showed exceptional ability to use profitably the less available or more slowly available forms of plant food.

Cold resistance.—Breeding work for cold-resistance in corn at the Wisconsin station (231) developed a strain of Golden Glow corn said to germinate when planted about 10 days earlier than usual. This strain was also characterized by early maturity.

Resistance to lodging.—None of the morphological characters in the cereals studied at the Minnesota station (108), except thickness of cell wall appeared to be closely related to lodging. In general, lodging in cereals may be said to depend upon so many factors of unequal value in the different sorts that no single factor seems to be closely enough correlated with it to be of much value as a selection index in cereal improvement.

Insect resistance.—Field observations in the presence of from moderate to severe chinch bug (second brood) infestation in southern Illinois, suggested that the greater yield of certain corn varieties is due to plant vigor as manifested by such varietal characteristics as large and sturdy stalks, well-developed root systems, and large leaf surfaces (54). The higher yield in White Democrat corn and several other corn varieties of Illinois seemed to be entirely due to their power to resist chinch bug attack (58). While both the roots and foliage of corn plants were heavily infested with aphids, none was discovered upon either the teosinte or teosinte×corn hybrids near by (56). Hybrid corns whose parent stocks came from Guam and Cuba appeared to resist the injury of the leafhopper more than imported corn belt varieties at the College of Hawaii (49) and were reasonably sure croppers, particularly in the lowlands.

In a comparison at the Kansas station (68) of 87 varieties of small grain, mostly wheat, the Hessian fly seldom laid eggs on oats, barley, einkorn, spring emmer, or durum wheat, and less abundantly on soft winter wheats than on hard winter wheats. Very few "flaxseeds" developed on certain varieties, notably Illini Chief, Dawson Golden Chaff, Beechwood Hybrid, and Currell Selection, although eggs were laid on the plants in abundance.

Observations at the Mississippi station (123) on the relative resistance and susceptibility of the bolls of different cotton varieties to boll-weevil attack seemed to indicate that varieties with the shorter boll periods, usually small bolled sorts, got beyond damage earlier than varieties requiring a longer period for development, which were generally large bolled.

Disease resistance.—Genetic studies made in conjunction with pathological investigations have produced results not only of scientific interest but possessing economic importance. Barren cornstalks and stalks bearing only nubbins appeared to be correlated with certain pathological conditions in the plants in cooperative studies by the Illinois station (57) and the United States Department of Agriculture. The genetic factors responsible for the reduced root systems in the strains of corn susceptible to root rot and leaf firing, respectively, appear to be recessive (59). Evidence at the Connecticut State station (34) from inbred strains of corn and their F_1 and F_2 hybrids suggested that susceptibility to smut (*Ustilago zeæ*) and a leaf-blight fungus is governed by factors capable of being segregated into some lines and not into others, the modification of the expression of parasitism by the vigor of the plants being a minor consideration.

Experiments by the United States Department of Agriculture conducted at Cornell University (168) yielded evidence that susceptibility to crown rust in Burt×Sixty-Day oats is partially dominant, while resistance is recessive, apparently due to definite genetic factors, although probably affected by nonhereditary factors. Rust resistance and susceptibility could hardly be considered as simple characters or determined by a single factor difference. At the Minnesota station (97) stem rust resistance in oats seemed to be inherited as a dominant character, depending on a single factor difference for expression. Rust reaction and panicle type did not appear closely linked in inheritance.

Resistance to smut in oats was completely dominant and apparently caused by multiple factors at the Washington station (226). Markton, a variety of common oats, was found to be immune from covered smut at this station (224). That some varieties of oats contain one factor pair for resistance to loose smut, whereas in other varieties two or three factor pairs may be concerned, is indicated by data obtained at Cornell University (174). The possibility of obtaining desirable types of smut resistant oats from crosses between resistant and susceptible varieties was indicated by the results.

Observations at the Kansas station (71) indicated three hard winter wheats that are resistant under Kansas conditions to a number of plant diseases, particularly stem rust and leaf rust. A selection of Fulcaster at the Pennsylvania station (190) seemed much more resistant to rust than most of the soft winter sorts, though less resistant than Crimean wheats, such as Turkey and Kanred. From studies at the Washington station (225), resistance of wheat to bunt, if Mendelian, is composed of multiple factors. Different wheat varieties possess different kinds of resistance, and linkage between resistance and morphological characteristics is not deemed sufficient to prevent the selection of a resistant strain of any morphological type desired.

Studies of a family derived from a durum-common wheat cross at the

North Dakota station (177) suggested that more than one factor is responsible for resistance to stem rust. Linkage was found to occur between the characters defining durum wheat and resistance to stem rust. Numerous distinct biologic forms of black stem rust (*Puccinia graminis*) have been isolated at the Minnesota station (112, 119, 120) from varieties of wheat. With the wheats used, it was found possible to combine in a single variety, resistance to two biologic forms of stem rust of wheat, when crosses were made between two varieties which reacted reciprocally to these rust forms. In work on the genetics of rust resistance at this station (102), immunity was found dominant, and a single factor was believed to determine the reaction to several forms of the rust.

Selections of varieties of cotton and of hybrids have been compared for wilt resistance at the Alabama (1) and Mississippi (121) stations and at the Georgia College of Agriculture (47). Potato hybrids showed varying degrees of susceptibility to wart disease at the Pennsylvania station (191) in work in cooperation with the United States Department of Agriculture. A hybrid potato blight-resistant in Hawaii (50) did not seem to retain this character on the island of Oahu. Strains of tobacco resistant to *Thielavia basicola* produced yields double those of infected strains at the Pennsylvania station (189). Susceptibility to this organism is considered recessive from studies at the Wisconsin station (236).

Baltic alfalfa showed resistance to a bacterial disease at the Colorado station (22), barley crosses to *Helminthosporium sativum* at the Minnesota station (98), flax selections to wilt at the North Dakota station (179), red clover selections to anthracnose at the Tennessee station (204), L–511 sugar cane to mosaic in Louisiana (76), seedlings of D. 109 and Java 36 sugar cane to mottling disease at the Porto Rico station (192), Yellow Caledonia sugar cane to gumming disease at the Porto Rico insular station (197), and a South American variety of sunflowers to rust at the Michigan station (93).

After three years' growth by the Minnesota station (103) of resistant flax varieties on clean soil the resistant qualities apparently were not lost in the absence of the wilt organism. According to preliminary indications, subsequent selection does not increase resistance to flax wilt with individual plant selections. Resistance to this disease appeared to be a dominant character at the Wisconsin station (230). High resistance to or even practically complete immunity from the leaf rust of rye (*Puccinia dispersa*) was shown by some sorts of rye at the Indiana station (61) in cooperative studies with the United States Department of Agriculture. Although resistance was probably dominant, complicating factors were suggested.

CONCLUSIONS

The scope and trend of breeding work with field crops in progress at the experiment stations during the last 20 years have been outlined in the foregoing review. The accomplishments are notable for their economic and scientific value, yet many problems remain to be solved. Among the promising lines for further research are investigations of the inheritance of earliness in certain cereals and cotton, studies of the characters concerned with yield, and genetic analyses of the factors involved in resistance to drought, diseases, insects, and to lodging and unfavorable soil conditions. Legumes, grasses, and the sorghums will undoubtedly receive more attention in the future. Additional cytological studies with important crops would supply much information essential to rapid progress in plant breeding investigations.

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STATION WORK IN HORTICULTURAL BREEDING

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A review of the fruit breeding activities of the agricultural experiment stations shows the tremendous awakening of interest coincident with the rediscovery of Mendel's law at the beginning of the present century (1).[7] Knowledge of the art of breeding had been accumulating for years, but no definite end beyond the development of improved varieties had been attained until light was received from the work of Mendel. Science, grasping the significance of his fundamental theory, took up the art of breeding and began to develop it slowly but surely into systematic knowledge. Progress has been necessarily slow because of the many fundamental features needing solution before real breeding work could be undertaken. Technique had to be developed and a knowledge of material obtained. Nevertheless, results have been secured that are not only valuable in themselves but point to much greater advances in the future.

MENDELIAN STUDIES

The discovery in 1901 of the real significance of Mendel's studies in inheritance, culminating in his theory of dominance and recessiveness and segregation and recombination of unit characters, had a far-reaching and very stimulating effect on breeding work in horticulture at the agricultural experiment stations. Up to this time most of the fruit and vegetable breeding projects were conducted by private individuals, whose single aim was the development of improved varieties. Mendel's hypothesis changed plant breeding from an art to a science. Nevertheless, the work of practical horticultural breeders (Bull, Campbell, Munson, Hovey, Stayman, and others) really constituted the foundation for the later progress and yielded many of the most profitable varieties of fruit.

Progress in the development of fundamental principles underlying the breeding of fruit and vegetables has been greatly handicapped by the heterozygous nature and long life of much of the material available for study. With the exception of certain vegetables naturally self-pollinating or capable of reproduction by self-pollination, progress has been necessarily slow. The Nebraska station (29), working with inheritance of characters, height, flower color, and seed color in the bean, was one of the first to report on the results of breeding work in the light of Mendel's discovery. The Virginia station (64), reporting upon tomato breeding studies, concluded that segregation and recombination occurred in accordance with Mendel's law, a declaration confirmed by work at the New York Cornell station (35) and by the New York State station (44). Comprehensive studies in tomato breeding were also carried on by the New Jersey stations (31). The Vermont station (57) found that Mendel's law held for the segregation of flower type in the carnation, and the New Hampshire station (30), working with the muskmelon, reached similar conclusions in regard to form and size of fruit, color, and netting of skin.

Records made in extensive fruit breeding operations at the New York State station have been summarized for several fruits. The apple breeding studies (38) indicated the difficulty of establishing inheritance laws for the fruit because of the blending, linkage, and existence of latent characters. Experiments with grapes (45) showed that selfing results in a loss of vigor in the seedlings. Crosses, on the other hand, yielded an unexpected proportion of poor quality seedlings. White, the only skin color found pure, was recessive to black and red. Investigations with raspberries (39) showed that purple-fruited berries are hybrids between the black and the red-fruited forms. As a result of studies of the inheritance of sex in strawberries (40), it was found that the crossing of perfect varieties yielded practically all perfect progeny, while crossing imperfect and perfect sorts yielded seedlings in the proportion of 1:1.

[7] Numbers in parentheses refer to references, p. 64.

The Iowa station (18) has carried on extensive breeding work with apples and pears in an attempt to breed hardy varieties. The North Carolina station (47) found that the fruit color in the Muscadine grape segregates according to the Mendelian ratio, white being pure and recessive to dark colors. This station also pointed out (49) that the floral types in *Vitis rotundifolia* are transmitted in definite Mendelian ratios. Recent studies at the New Jersey stations (32) suggest that the various types of foliar glands in the peach are inherited as Mendelian units. Extensive breeding work with apples and crab apples at the Illinois station has been reported upon at frequent intervals (16).

PURE LINE STUDIES

The Johannsen theory that ordinary commercial varieties of self-fertilized plants are made up of a number of pure, constant lines which once isolated can not be further improved by selection (2) has been utilized in breeding work by the stations, particularly in the isolation of high-yielding, vigorous strains of vegetables. The Pennsylvania station found large variations in the yielding capacities of cabbage (54) and tomato (55) of a single variety obtained from different seedsmen. Similar results were obtained by the Indiana station (17) and by the Virginia truck station (66). The Vermont station (58) and the Minnesota station (28) showed that the Hubbard squash, an important commercial variety, is ordinarily comprised of numerous component strains of differing fruit shapes, productivity, etc., that can be separated and perpetuated by self-pollination. The isolation of pure lines of Alaska pea was successfully accomplished at the Minnesota station (26).

STERILITY STUDIES

Previous to the rediscovery of Mendel's work, several of the American experiment stations were busily engaged in determining the pollinating capacities of many of the fruits. The importance of such knowledge was indicated in the failure of earlier horticulturists to recognize unisexuality in the strawberry, the existence of which led to many failures until the problem was finally solved in the slow and hard school of experience.

One of the first fruits to be studied in respect to sterility was the grape, the New York State station (43) and the Minnesota station (22) reporting at about the same time that many varieties are partially or fully sterile. Work at the Georgia station (14) helped to confirm these conclusions. The North Carolina station (46) reported that a large proportion of the Muscadine grape varieties are self-sterile.

That self-sterility is the rule in American plum species was indicated by work at the Vermont station (59, 60) and by the Wisconsin station (70). Work with the European plums at the Oregon station (52) and at the California station (4) showed that self-fertility is much more prevalent in this than in the American group.

Sterility studies with the apple, reported by many different stations, Vermont (62), Delaware (7, 9), Oregon (50), Minnesota (27), Maine (20), and Maryland (21), showed a surprising number of sterile or partially sterile varieties. The Delaware station (6, 8), the Virginia station (65), and more recently the California station (5) have reported upon work with pear varieties. Cherry varieties were studied at the Oregon station (51) and the New York State station (42). One fruit, the peach, was found largely self-fertile (10) until recent work at the New Jersey stations (34) indicated that there are exceptions, for example, the J. H. Hale variety.

Sterility observations have not been confined to fruits, studies of the almond being reported by the California station (3), of the filbert by the Oregon station (53), and of the pecan by the Georgia station (12).

CAUSES OF STERILITY

Not satisfied with the discovery of the existence of sterility in fruits, investigators have strenuously sought to determine the fundamental causes of failure to set fruit.

The Wisconsin station (72) studied the effects of humidity and temperature on the development of pollen grains. The New York State station (36) showed that the pollen of self-sterile grapes was incapable of growth in favorable media. Cytological studies at the Minnesota station (23) indicated that pollen sterility in the grape probably results from degeneration processes in the generative nuclei. At the North Carolina station (46) it was found that Muscadine grape varieties having reflexed stamens bore anthers containing defective pollen and required the presence of male

vines for pollination. The New York State station (41) pointed out that all grades of sex development exist in the cultivated grape, ranging from complete maleness to complete femaleness. An attempt by the Georgia station (13) to determine the underlying causes of self-sterility in *Vitis rotundifolia* confirmed the Minnesota conclusions (23), namely, that pollen of sterile vines develops normally for a time, until a degeneration occurs in generative nuclei.

Working with American species of plums, the Minnesota station (25) reported that sterility and cross-sterility are not due to pollen abortion but to the failure of the pollen tube to grow rapidly enough to insure the fusion of the gametes. Slow pollen tube development was observed in the Rome apple, at the West Virginia station (68). Sterility of the J. H. Hale peach was found by the New Jersey stations (33) to be due to the failure of the variety to develop viable pollen. Studies at the Minnesota station of the sexual condition in the strawberry (24) revealed no physiological sterility. The discovery of sterile pistils in some of the later flowers on an inflorescence was believed due to the diœcious ancestry of this fruit.

Working with wild species of Rubus, the Vermont station (63) reported that all species are either completely or nearly self-sterile, sterility in the blackberry being due to defective pollen. Self-sterility, discovered by the North Carolina station to be a common occurrence in the dewberry (48), was believed due to *Rubus trivialis* ancestry, the tendency to self-sterility being apparently transmitted not only to pure but to hybrid progeny. That hybridity is often a cause of sterility in fruits was early pointed out by the Vermont station (61). Various station investigators have observed that self-incompatibility, or the failure of the flower to set fruit in the presence of healthy pistils and viable pollen, is a frequent cause of self-sterility. The Wisconsin station (69) observed that trees exhausted by overbearing, drought, or soil poverty had a marked tendency to produce more defective pistils than normal trees. Cold and rainy weather during the blossoming season materially affects fruiting (37, 72).

BREEDING FOR DISEASE RESISTANCE

Studies at several of the stations have shown that susceptibility to disease in certain plants may be overcome, in part at least, by breeding.

The Virginia truck station (67) produced a mosaic-resistant spinach variety known as the Virginia Savoy by hybridizing the ordinary Savoy with a wild Manchurian form. The Wisconsin station (71), by continued selection under field conditions, has developed strains of cabbage resistant to yellows (*Fusarium conglutinans*). Work at the Georgia station (11) indicated that blossom-end rot resistance, observed in the cherry tomato, is transmitted to progeny of crosses with standard varieties. The Illinois (15), Louisiana (19), and Tennessee (56) stations reported satisfactory progress in the selection of tomato plants resistant to fusarium.

PRACTICAL RESULTS

Incidental to the accumulation of scientific material, many of the stations have made serious efforts to develop valuable varieties. Perhaps this work has been most highly developed at the New York State station, from which several very promising fruits have been disseminated, one of which, the Cortland apple, is already taking a prominent place in American pomology. The South Dakota, Minnesota, and Iowa stations have been successful in breeding fruits combining quality and ability to survive cold winters. Breeding work at the New Jersey stations has yielded several meritorious peaches, one of which is being disseminated under the name "Pioneer." Many of the other stations, Idaho, Maryland, etc., have large collections of promising apple, pear, grape, and other fruit seedlings under trial.

SUMMATION

The discovery of Mendel's law, De Vries's theory of mutation, and Johannsen's pure-line hypothesis opened a new era in the breeding of horticultural plants, the agricultural experiment stations being among the first institutions to realize the significance of these epoch-making concepts and to put into practice the ideas set forth. In the two decades that have elapsed fair progress has been attained, as indicated by the numerous publications upon the subject from various experiment stations. Much more rapid developments may be anticipated in the future because of increase in workers trained in plant breeding and associated subjects and because of the fact that much fundamental knowl-

edge is now at hand to serve as building material for the future.

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INVESTIGATIONS IN ANIMAL GENETICS AT THE EXPERIMENT STATIONS

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Since the rediscovery of the fundamentals of Mendel's law in 1900 by DeVries in Holland, Von Tschermak in Austria, and Correns in Germany, the increasing recognition accorded the results of genetic investigations has been gratifying. At first the practical application of Mendelism was not so clear with animals as with plants, but largely because of the early work of Bateson in England, Cuenot in France, and Castle and Davenport in America its application to animal breeding became apparent. The present knowledge of the behavior of characters in inheritance is, however, so incomplete that the animal geneticist can do little more than attempt to offer explanations for what has occurred in breeding operations.

Distinctly more progress has been made with plants than with animals, but the problem is very different. Characters of economic importance, such as conformation, fecundity, and milk production, are evidently inherited in a very complicated manner and it is furthermore impracticable to have the numbers for selection in animal breeding that are available to the cereal investigator for example, who may use for continued breeding only a few plants selected from the thousands produced. The impracticability of doing this with cattle is evident when we consider that one offspring annually is the best that can be expected from a selected female, and that only after she has reached two years of age. Considering this handicap, it must be admitted that the founders of our present breeds of livestock were surprisingly successful. Analyses by geneticists of the methods used by the early breeders have shown that, though they did not understand the present accepted laws, they followed closely the now recommended principles of breeding and understood in the main the results to be expected from various types of matings.

Research in animal genetics has only just begun. Investigations have been slow in furnishing results, not only because of the time required but because of lack of training of many of the investigators. Distinct progress has, however, been made, notwithstanding this handicap. Before the rediscovery of Mendel's paper, Weisman had already associated hereditary factors with the chromosomes, which seemed to be the only constant and conspicuous bodies carried by both the ova and spermatozoa. This hypothesis has not only been corroborated in the more recent work, but in the extensive studies with the pomace fly (*Drosophila melanogaster*) by T. H. Morgan and associates at Columbia University the theoretical location in the chromosome of the genes determining hundreds of characters has been effected. Furthermore, the phenomena associated with crossing over, nondisjunction, polyploidy, etc., have been clearly demonstrated in the laboratory with this fly. In so far as it has been possible to determine, the same principles are generally operating in the determination of characters in plants and animals.

Numerous publications on Mendelism in animals followed the early papers. The State agricultural experiment stations have contributed a large number of such papers, especially in more recent years, on the inheritance of characters in the domestic animals. The stations have had an advantage in this respect, since nearly all of them have herds of the various farm animals which are available for preliminary investigations at least. Furthermore, data are available in the form of herdbooks and records of milk production and egg-laying contests with which those working in agriculture are more familiar than geneticists at other institutions. The stations have perhaps not contributed so much toward the new and fundamental problems as might be expected, but since the greater part of this work has been done with the larger animals the explanation is obvious.

CHROMOSOME STUDIES

Studies of the chromosome numbers and behavior during gametogenesis require proficiency in technique, and few investigators have carried on

such work with the domestic animals, although it is the correlation of the theory with the actual cytological observations that has given added weight to the theoretical laws of heredity.

Cytological studies have been made at the Idaho experiment station with all of the more common domestic animals and the chromosome counts determined on at least one sex in each case. The horse has been found to produce sperms (21)[8] containing 19 and 17 chromosomes in approximately equal numbers, and it is assumed that the diploid number in females is 38. The ass has, however, 65 chromosomes (22). The mule thus results from the fertilization of a 19-chromosome ovum by a sperm carrying 32 or 33 chromosomes. In consequence, reduction divisions in the mule are abnormal and the pairing of the chromosomes during reduction was observed to be incomplete and inconstant, no normal sperms being formed. In the pig (20) the somatic cells of the male contained 18 and the female 20 chromosomes. Observations of spermatogenesis showed that the sperms formed contain 8 and 10 chromosomes in equal numbers.

The spermatogonia of adult bulls (23, 26) and the somatic tissue of male fetuses showed 37 chromosomes, with the odd chomosome (sex), which was larger, passing undivided to one pole at the first spermatocyte division. Two sex chromosomes were also observed in the oogonia of female embryos. In sheep (24) the spermatogonia and somatic cells of male embryos were found to contain 33 chromosomes, while the oogonia and somatic cells of females contained 34. The spermatocytes contained 16 and 17 chromosomes in equal numbers, while all ova contained 17 chromosomes. Measurements of the mature spermatozoa of the horse, pig, and sheep showed a definite dimorphism in the head length, while the ova were all of a similar type.

The large numbers of chromosomes in these animals give an indication of the difficulties involved in the location of the genes in the different chromosomes and of the establishment of linkage relations.

SIMPLE MENDELIAN INHERITANCE

The behavior of colors in crosses is so much more striking and easier to follow than other characters that much progress has been made in determining the genes responsible and their behavior, and in case of rats, mice, and rabbits linkage relations have been established with a few such characters. These results bear out the fundamental principle of the chromosome as the carrier of the genes in determining the mode of the inheritance.

The Wisconsin station made an analysis of the cause of red calves occurring as purebred offspring of the black breeds (358). It was found that some of the foundation animals in the Angus, Galloway, and Holstein breeds were red. It was pointed out that red is inherited as a simple recessive to black, and the occurrence of red animals meant that both sire and dam were heterozygous for this character. This station also determined in crosses between Jersey-Angus and Holstein-Angus cattle that the polled condition and black color were dominant (352, 353). Scurs appeared on some of the heterozygous polled individuals, especially in males.

Similar results in regard to the black color and polled condition were obtained at the Maine station (112) in crosses of the principal dairy breeds—Holstein, Guernsey, Jersey, and Ayrshire—with Angus cattle. White markings in the inguinal region appeared dominant, while other white markings were in general suppressed by the solid color. The pigmented muzzle and tongue were dominant to the lack of pigment. The black of Holsteins acted as a simple dominant to the red of Guernseys in studies at the Illinois station (28). Crossbred Galloway-Holstein cattle produced at the Alaska station (1) were described as polled black, with more white on the underline than Galloways and resembling Holsteins in hair characters and conformation.

The behavior of colors and horns in crosses of Shorthorns and Galloways has been studied at the Iowa station (50). The black and red pigment form an independent pair of allelomorphic characters. White animals appeared to be due to restricted pigment lacking the dominant extension factor and thus were genetically either blacks or reds. Roans were equally well explained as due to a dominant factor for roan or as the heterozygote for the extension factor. Whites with black ears have appeared in these experiments, but the reverse has not been observed. The horned and polled

[8] Numbers in parentheses refer to references, p. 75.

conditions were shown to be allelomorphic and without evidence of sex linkage. Studies at the Kentucky station (105) indicated that the yellow nose of the Jersey acted as a simple recessive to gray nose. The inheritance of defects in the teeth (348), congenital cataract (38), albinism (30), and a hereditary enlarging of the ears (328) have been described by the Wisconsin, Illinois, and Texas stations.

In a rather extensive study by the Kentucky station (100) of color inheritance in horses, based on studbook records, chestnut appeared to be recessive to all other colors, black was shown to be a simple dominant to chestnut, while bay was black with a dominant restriction factor and gray was due to a factor dominant over all other colors. A factor for roan may also be present which in the dominant condition produces various shades according to the other colors present.

Colors are obviously less conspicuous in their inheritance in sheep than in horses and cattle, but an abnormality in the form of an earless condition acted as a simple Mendelian dominant at the New Hampshire station (285). Sheep heterozygous for this condition had short ears (286).

Color inheritance in swine was investigated at the Kansas station (71, 96) by crossing wild boars, Tamworths, Berkshires, and Duroc-Jerseys. It was found that the Berkshires carried a single dominant factor which caused black, in the absence of which two dominant factors carried by Durocs acted, the presence of either one causing sandiness or both together causing red. A dilution factor linked with black may inhibit the action of one of the factors for sandiness. A single factor for immature striping and a hypostatic factor for black spotting were carried by the wild boars and by Tamworths.

In studies at the Iowa station (52), the Hampshire black was dominant to Duroc-Jersey red and differed from Berkshire and Poland-China black, since the offspring of crosses of the latter two breeds were predominantly red with black spots. Furthermore, Berkshire and Poland-China black was recessive to the white of Chester-Whites and Yorkshires, while crossbred Hampshire × Chester-Whites were in general blue roans having a white belt. In crosses of mule-foot boars with Duroc-Jerseys at the Illinois station (32), the black color and syndactylous condition were dominant. The operation of intensifying factors was suggested by the variability in the red of the F_2 offspring. The unpublished results of experiments in which a Cheshire boar was crossed with Essex sows at the New York Cornell station showed that the F_1 pigs were white with a few black hairs. The F_2s produced were classified as 34 white, 11 black, and 4 spotted.

Color inheritance in poultry has been studied at several of the stations. Factors were designated for determining various colors in fowls as a result of experiments at the Connecticut station (9). E^m was designated as responsible for extending black to all parts of the plumage, while the recessive e^m restricted the black to the wings and tail (buff and Columbian). The sex-linked factor S determined silver as in the Columbian and duckwing patterns, while s was not silvered. The action of E^m was confirmed at the Kansas station (69) and was shown to be distinct from E, which was involved in the production of black in the presence of a factor P. Black was restricted by R to blue in Andalusians (65). A factor I^p in Leghorns inhibited the action of P to produce white. The massing of black in contour feathers may be due to a fourth factor. At the Missouri station (274) spangling was found to be due to a sex-linked factor and hen feathering in Sebright bantams to be a dominant non-sex-linked factor.

An extensive series of investigations on the inheritance of color in pigeons has been conducted at the Rhode Island and Wisconsin stations (319, 373, 374, 375). These include detailed genetic analyses of various colors and patterns, microscopical and chemical studies of feather pigments, linkage relations of certain sex-linked characters, and a detailed study of the factors involved in the production of checks, bars, and other modifications of black.

Laboratory animals have also been used to some extent for studies of color inheritance by the stations, but not to the same extent as at other institutions. At the Wisconsin station (366) a synthetic pink-eyed self-white guinea pig having all the characteristics of an albino but genetically colored was produced. This station likewise proved the factors for black, tortoise, and yellow in this animal to form a multiple allelomor-

phic series. Congenital palsy in the guinea pig was found to be inherited as a simple Mendelian recessive (357). A series of papers also published from this station (362, 363, 364, 365) dealt with tricolor inheritance in the guinea pig, basset hound, and tortoise-shell cat.

Linkage relationships in rats and mice were studied at the Wisconsin and Illinois stations. In the former case (367), the linkage of redeye, albinism, and pinkeye in the rat as reported by Castle was confirmed, but a lack of linkage was found between the red-eyed allelomorphs and the self-Irish-hooded set of allelomorphs, between redeye and agouti, and between agouti and self, thus indicating that the five known sets of allelomorphs concerned with coat color in rats belong to three linkage groups. At the latter station, no linkage in mice was observed between the agouti, dark-eyed, and black body factors.

One of the most extensive series of allelomorphs known has been reported in the genus Paratettix from the Kansas station (74, 75, 76). In this grasshopper 14 different color patterns are considered to form a series of multiple allelomorphs.

SEX DETERMINATION AND SECONDARY SEX CHARACTERS

The hypothesis that the male is heterozygous and the female homozygous for the sex chromosomes has not only been well established genetically by means of sex-linked characters, but cytological studies have definitely shown such a condition to exist in the domestic animals (20, 21, 22, 23, 24, 25, 26). In poultry the evidence points toward a slightly different mechanism, in which the female is heterozygous and the male homozygous for the sex-determining chromosome, although the results of cytological studies have hardly been numerous enough for a complete confirmation of this hypothesis.

The Wisconsin station, using rabbits as the experimental animals, attempted to separate the male- and female-producing sperms by centrifuging the semen, but the results were negative (341). Using the same animal, the effect of excessive sexual activity on the sex ratio and other characters was investigated at the Iowa station (53, 54). Repeated services by bucks of upward of 20 times in three hours resulted in a decrease, at the fifteenth and particularly the twentieth service, in the amount of semen recovered, the number of sperms produced, the proportion of sperms showing normal movement, the amount of movement, and the percentage of pregnancies. No decrease in the litter size was observed except at the twentieth service. The offspring were in no way inferior in size or vigor, although there seemed to be a low proportion of males with the heavy service. It was concluded that excessive sexual activity exerted a selective action on the sperm cells, eliminating the majority of the male-producing spermatozoa, while the larger female-producing sperms showed lower mortality and greater endurance or for some other cause were superior to the smaller male-producing cells.

The Kansas station (64) found in guinea pigs that the sex ratio was not influenced by the litter size, season of year, still-born animals, or those dying before 20 days of age, but the age of the dam seemed to have an influence on the sex ratio, as females 15 months old gave ratios in their offspring of 145 males to 87 females, whereas females 8 months of age produced 192 males to 224 females.

The practical application of sex-linked characters for the determination of the sex of crossbred chicks at hatching was demonstrated at the Connecticut station (15).

The Massachusetts station has conducted a number of investigations with fowls and ducks dealing with the physiological factors affecting the development and modification of the secondary sex characters (238, 241, 243, 244, 245, 246, 248, 250, 252, 253, 256, 257, 260). The effect of castration, ovariotomy, seasonal activity, and histology of the testicles was observed. The Maine station has published a series of 11 papers on sex and the factors affecting secondary sex characters in poultry, cattle, and mice (135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145), and is still conducting other studies. In the investigations with poultry the ovaries and testicles of birds were carefully examined microscopically for determining the influence of corpora lutea, lutein tissue, interstitial tissue, and other components of the gonads on the determination of secondary sex characters. From the results of these and other studies, it was concluded that pathological changes in the gonads tend to cause a change of the secondary sex characters toward those of the opposite sex at the next molting.

The cause and exact nature of free-martins have long been matters of much speculation among cattle breeders and geneticists alike. In a study at the Maine station of the frequency of occurrence of identical twins in cattle (130), it was found that they were very rare. This led to the conclusion that the theory of the free-martin being an undifferentiated male formed by the division of a single male-producing egg is doubtful.

The chromosome control of sex has been generally accepted ever since its discovery by C. E. McClung. In recent years the operation of other factors in sex determination has been indicated so that what have been called intersexual individuals were produced having the genetic constitution of one sex but modified toward the other sex by the operation of other factors. One of the most striking of such cases was described by F. A. E. Crew, in which a hen which had laid eggs developed the secondary sex characters of a cock and finally mated with hens and produced fertile eggs. C. B. Bridges has shown cases of intersexuality in the pomace fly to be due to abnormal relations between the numbers of sets of autosomes and sex chromosomes, while R. Goldschmidt in Germany has explained the intersexual individuals appearing in gypsy-moth crosses as due to variations in the strength of certain strains for maleness and femaleness.

INHERITANCE OF QUANTITATIVE CHARACTERS

Most of the characters in animals which are closely associated with their economic value are not so easily followed in their mode of inheritance as are color and sex. Some of the reasons for this are obvious. Milk and egg production and fertility may be taken as examples. A large number of environmental as well as hereditary factors are working in a closely interrelated manner and exerting a stimulating or depressing influence in determining such characteristics, i. e., food, season, temperature, etc. When the effects of environment are eliminated as far as possible, there is still very good evidence to show that a large number of genetic factors are responsible for milk production, which, because of their closely related interactions, it has been impossible to separate.

Inheritance of milk production.—The action of multiple factors in determining fat percentage was found to occur in a study at the Illinois station of the factors affecting butterfat percentage and milk yield carried out by crossing Guernseys and Holsteins (39). From an analysis of the data accumulated in this experiment in which 47 F_1 and 19 F_2 individuals were produced, it was calculated that 14 genetic factors were involved in the determination of fat percentage. The results of studies of the inheritance of milk and fat production at this station (40), based on records of cow-testing associations and the advanced registry records of the various dairy breeds, led to the formulation of the hypothesis that the energy of the milk produced was the limiting factor in milk production. The conclusion followed that the possibility of combining high milk and fat production in the same individual was highly improbable.

In crosses of Angus cattle with the principal dairy breeds (113, 114) at the Maine station, high milk production proved dominant to low milk production, but high fat percentage was recessive. Angus cattle have also been crossed with Jerseys and Holsteins at the Wisconsin station in a study of the inheritance of milk and meat production (350) with similar results.

The advanced registry records of the dairy breeds furnished many data which formed the basis for a large number of statistical studies at the Maine station on the factors affecting milk and fat production and their inheritance. A part of these results were published as a series of 14 papers on milk secretion (174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187). Several of them dealing with the influence of different ancestors and relatives on milk production and the relation between sisters, cousins, etc., were published in a book (131) dealing with milk secretion in Holstein-Friesian cattle, while many others appeared separately. The results of such statistical work are valuable in furnishing some idea of the variability to be expected in milk production and fat percentages within breeds, and they are particularly valuable from the standpoint of the correlations found between the production of relatives and ancestors. The fallacy of placing weight on distant ancestors because of their outstanding achievements in the way of production in estimating an animal's ability was substantiated. The sire and dam were shown to be equally responsible for the milk yields and fat percentages of their offspring, not only through the correlation coeffi-

cients of parent and offspring but by the approximate equality of the coefficients obtained in correlations between the paternal and maternal granddams and their granddaughters.

The effect of the age of the parent on the offspring's production was investigated by the use of herdbook records at the New York Cornell station (303) with negative results. Pregnancy was found to diminish production in studies at the Kentucky (107) and Missouri (271) stations.

Fertility.—Although milk and fat production are quantitatively determined by an undoubtedly large number of factors, these characters, nevertheless, have an advantage over fertility and body conformation when a genetic analysis is to be made. Definite and complete records are available for the production of individual dairy cattle for periods of various lengths. This is not so with fecundity, and no general records are kept of conformation. The records of registered purebred offspring of individual breeds are kept, but so many of those produced are never registered that studies on the number of offspring based on such records would be of no value.

Most of the fertility work has been done with poultry, in which case egg production is very close to if not the criterion of fertility and this is also the product for which poultry is mainly kept. Flock records and the results of egg-laying contests have been used as raw data for studying seasonal variations in production and the factors responsible for the inheritance of egg production at various of the stations, including Maine (201, 205, 226, 227, 228, 229, 231), Massachusetts (262), New Jersey (293, 294, 295, 296, 297, 298), and Utah (336, 337). Undoubtedly the most definite results from a study of a problem of this sort were obtained at the Maine station (171), in which two factors (one sex-linked) were found responsible for winter egg production. In the double homozygous recessive condition, no winter eggs were produced. When either factor was dominant, either homozygous or heterozygous, less than 30 eggs were produced, but with the presence of the dominant form of both factors over 30 eggs were produced in the winter.

This case is particularly significant in that it points out in a definite way what has been expected to exist in a very complicated manner in the inheritance of quantitative characters. It is unfortunate, however, that these factors do not apply generally to poultry, as a study of the records at the Massachusetts station (251, 255) did not confirm the operation of the sex-linked factor, but a second nonsex-linked factor was indicated. The use of rate of production rather than total production for a period was suggested as a better basis for future work, since the winter laying period of pullets depends on the date of hatching. In studies at this station two factors were indicated as responsible for broodiness (261) and another factor for rate of production (251).

Statistical studies of the data accumulated in the New Jersey egg-laying contests (294, 295) did not indicate that different factors are operative in controlling winter egg production from the factors responsible for production during the rest of the year. In studies at the Rhode Island (321) and New York Cornell (304) stations. the inheritance of characters concerned with the eggs produced, such as color, shape, size, etc., was indicated, but an analysis of the factors involved was not made.

The length of the eggs laid by *Drosophila melanogaster* was found at the Kansas station (80) to be inherited. Several factors were responsible, the major one being sex-linked, while another important one was located in the third chromosome.

The few studies which have been made of fertility in farm animals have been mostly very elementary in nature, and the data obtained have not been sufficiently complete for a detailed genetic analysis.

Conformation and body characters.—The inheritance of differences in type has been studied in cattle, sheep, and swine. In the crosses of the dairy breeds with Angus cattle at the Maine station (112, 113, 114), the type of head and heavy deep-fleshed fore quarters of the Angus were dominant, while body and hind quarters appeared mainly intermediate but showed some resemblance to those of the dairy parents. In crosses of Jersey and Angus cattle at the Wisconsin station (353), no genetic analysis has yet been attempted, though the conformation of the crossbreds tended to be intermediate. The Texas station (327) is studying the inheritance of characters in crosses of Brahman cattle with grade Herefords. The crossbred calves were found to grow more rapidly than purebreds.

An extensive study of the inheritance of size and conformation in

crosses between mutton and fine-wool sheep has been made at the New Hampshire station (292). This experiment consisted mainly in measuring the F_2s and F_3s of Southdown × Rambouillet crosses. Such individuals were smaller than F_1s and their conformation was better than that of Rambouillets but not so good as Southdowns. The wool approached Rambouillet quality in fineness, crimp, and length but had less grease. The growth rate of the animals to 4 or 5 months depended on the dam's milk yield. The general characteristics were usually intermediate in the F_1 with increased variability being evident in the F_2s. These results indicated segregation of the factors concerned in determining size, but there was no evidence of dominance. In making a study of the internal characters, animals of each generation were slaughtered and transections of the carcasses made. The hybrids showed a length of rib similar to the Southdowns but resembled Rambouillets in the width of the thoracic cavity at the base and in the length of the spinous processes, which was closely correlated with the thickness of flesh. Oxford and Rambouillet crosses are being used to study the inheritance of fecundity and milk production.

Studies on the inheritance of wool characters and conformation are being conducted at the California (5), Wyoming (377, 378), and Texas (332), stations, although the results are as yet only preliminary.

Work at the Kansas station (71, 96) has tended to throw some light on the inheritance of breed characteristics in swine. In the crosses the erect ears of the Berkshires were dominant by probably three factors over the lopped ears of Duroc-Jerseys. The face of the wild hog was dominant over the other types of faces, while the shape of the Tamworth's face was dominant to the dished Berkshire face, and the Berkshire was largely but not completely dominant to the Duroc-Jersey type of face. The forehead shape of the Berkshire seemed to be more dominant in crosses than the dish or the length of the face. The number of mammæ was found to be inherited in a general way. There was no greater tendency to variation in the rudimentary nipples of males than in the nipples of females. As the number of mammæ increased there was an increase in the percentage of asymmetry in the pattern, and sows having a larger number of mammæ were found to produce more offspring than sows with the smaller numbers. The paired rudimentaries to the rear of the inguinal pair were observed to be inherited as a simple sex-linked Mendelian character.

The Kansas station (62) is studying the inheritance of size in rats by endeavoring to select pure lines among the descendants of a very large male mated with an ordinary sized female. A male larger than his sire was produced in the F_1 generation.

Summary.—Investigations of the inheritance of quantitative characters have hardly progressed far enough for more than the formulation of the hypothesis that such characteristics are controlled by multiple factors, as H. Nilsson-Ehle found for color in wheat. Many factors, some of which inhibit the action of others, and variations of the relative influence on the character in question further complicate the situation.

The stations have made an excellent beginning in work on the inheritance of milk production which should yield results of much economic importance. The Illinois station has the Bowlker herd in which breeds naturally producing high and low flat percentages in the milk have been crossed, while the Wisconsin and Maine stations have several generations resulting from crosses of the beef and dairy breeds of cattle. A continuation of such projects may be expected to yield many important results in the next few years.

METHODS OF BREEDING

Much material has been published on the advantages and disadvantages of various methods of breeding livestock. A great many popular papers have been very contradictory in their recommendations, as have also the results of some of the experiments conducted, especially on inbreeding. The Maine station published several papers (188, 189, 190, 191, 192, 193, 194, 195) under this title which were based on the available scientific knowledge, and coefficients for calculating the amount of inbreeding were suggested, but even this work has been strongly criticized in recent years.

The experimental work in inbreeding conducted at the experiment stations hardly compares either in extent or thoroughness with the investigations of H. D. King with rats and S. Wright with guinea pigs, but the station work, nevertheless, has

tended to throw some light on the effects of inbreeding with other classes of animals and pointed out the difficulty of predicting what results are to be expected, since the success or failure of inbreeding will depend on the constitution, vigor, and other characteristics of the original stock. In studies of inbreeding with hogs at the Delaware station (17), it was found that inbreeding tended to decrease the certainty of pregnancy, increase mortality, and decrease litter size, although the individual weights were greater. The results of several years continued inbreeding of dairy cattle at the Ohio station have shown no decrease in fertility, but the milk production and size have decreased.

Two inbreeding experiments with poultry have been conducted at the Wisconsin station (355). In one of these, inbreeding by brother and sister matings of Rhode Island Reds, in which selection was made only for desirable color, resulted in decreased viability and hatchability of the eggs from 1912 to 1916, but by starting with new stocks for the second experiment and making selections for hatchability and vigor no deteriorations resulted in the flock bred by similar methods from 1917 to 1921, although later generations have shown some deterioration in vigor. Similar experiments at the Connecticut Storrs station (14) resulted in a rather general and uniform decline, although there was some variability among the different lines. This applied particularly to the percentage of eggs hatched, the number of eggs laid in the first year, the mortality both of chicks to 3 weeks of age and of adult pullets, the growth rate of chicks, rate of sexual maturity, winter egg production, and probably the activity of the vital processes.

At the Massachusetts station (263) inbreeding of Rhode Island Reds tended to decrease winter egg production, and the rate of maturity was retarded. Different lines, however, showed significant differences in production. Inbreeding guinea pigs in experiments at the Kansas station (60) did not produce any decrease in vigor, fecundity, or size.

The composite results of inbreeding experiments, though somewhat contradictory, have tended to bring out the conclusions which have been arrived at in other work on inbreeding in plants and animals, namely, that the main tendency is for a production of homozygosis in the individual lines with consequent reduction in vigor and fertility. It has been suggested that the factors determining these characters are largely dominant, and the production of homozygosis tends to eliminate some of these dominant factors with a resulting decrease of vigor.

PHYSIOLOGY OF REPRODUCTION

That phase of animal genetics dealing with the physiology of reproduction has not received the attention which it has deserved. Work along this line may be expected to yield results which will add important contributions toward the solution of the more intricate problems closely associated with the practical application of the subject. Little is known of the fundamental physiological activities associated with the vital processes. This is particularly true of the processes underlying the determination of secondary sex characters, fecundity, and milk production.

One of the first extensive series of papers on this subject dealt with the physiology of reproduction in the fowl and consisted of 19 papers issued by the Maine station (147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165). These studies dealt with the environmental influence on egg production as well as the influence of internal secretions and the effect of endocrine organs on production. The effect of continued administration of alcohol on the progeny of domestic fowls was also studied at this station (210, 213, 214, 215). As a result of the administration of alcohol, the prenatal mortality was increased, but the postnatal mortality was reduced. Similar results were obtained when the fertile eggs were exposed to alcohol fumes.

Efforts to modify the germ plasm at the Wisconsin station (345, 354) by the use of various toxins were mainly negative in result, sterility being the only evidence of a modification. A waltzing rabbit (360), however, occurred among the descendants of individuals treated with lead and alcohol, which was concluded to be due to an injury to the germ plasm of its ancestors.

The effect of the somatic cells on the germ cells was studied at the New York Cornell station (305) with poultry, much as Castle and Philipps did with guinea pigs. The results obtained at the Cornell station were, however, not in accord with those obtained with guinea pigs. The trans-

ference of ovaries from white birds into black hens resulted in the production of spotted offspring when mated with white roosters.

The position of fetuses in the uterus was studied at the Kansas station with guinea pigs (64) and the results indicated that crowding affected the weight of the placenta which in turn reduced the size of the fetuses.

In investigations at the Kentucky station (101), the semen of stallions, bulls, roosters, and man was studied with regard to the composition, length of life, acidity, and other properties. The primary purpose of this investigation was to throw light on the factors affecting sterility in animal breeding, and further to see how long semen could be kept for artificial insemination. Normal horse semen was found to vary in pH value from 6.94 to 7.51, with an average of 7.31, while inactive semen varied from 7.49 to 7.76. It was found that the spermatozoa of vigorous horse semen kept in the laboratory at 22° C. began to decrease in movement in 2 hours, followed by complete loss of movement in 6 hours. Other temperatures below and above this were less satisfactory. The addition of solutions of 0.045 per cent hydrochloric acid, sulphuric acid, nitric acid, acetic acid, or carbolic acid, 0.0067 per cent potassium permanganate, or 0.25 per cent ethyl alcohol, immediately stopped all activity of the spermatozoa of the horse. From examination of mares and hens killed at intervals after breeding, it was concluded that the secretions of the genital tract tended to prolong the life of the spermatozoa as active sperms were found in all hens from 6 to 8 hours after breeding and in one mare 7.25 hours after insemination.

CONCLUSION

The work of the experiment stations in animal genetics, supplementing that of other institutions, has dealt with various phases of the subject and with different kinds of animals but especially the larger animals. The general status of the work points toward the need of much more data on the inheritance of the characters of economic importance. It may not be possible to accumulate sufficient data at one institution for a proper analysis of such characters, especially in the larger animals. Herein may lie an opportunity for cooperative experiments in which several institutions have a part. The fundamental physiological factors underlying reproduction have likewise not received the attention which they deserve, and progress is at a standstill in certain lines of work until more is known of the physiological factors related to reproduction and development.

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(376) Heller, L. L. Reversion in sheep. Jour. Heredity, 6 (1915), No. 10, p. 480.

(377) Hill, J. A. Studies in the variation and correlation of fleeces from range sheep. Wyo. Sta. Bul. 127 (1921), pp. 39–52.

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PUBLICATIONS OF THE STATIONS, 1924

The following is a classification of station publications received by the Office of Experiment Stations during the year. Only publications of the regular series issued by the stations are listed. It has not been practicable to list other publications, but it may be of interest to note that during the period covered by this report approximately 60 papers originating in the experiment stations were published or accepted for publication in the Journal of Agricultural Research.

AGRICULTURAL CHEMISTRY—AGROTECHNY

Studies with phytosterols: Phytosterols of corn oil, cottonseed oil and linseed oil. R. J. Anderson and M. G. Moore. (N. Y. State Sta. Tech. Bul. 95, pp. 16. Aug., 1923.)

Chemical studies of grape pigments: The anthocyans in Norton and Concord grapes R. J. Anderson. (N. Y. State Sta. Tech. Bul. 96, pp. 19. Aug. 1923.)

A chemical study of legumes and other forage crops of western Oregon. J. S. Jones and D. E. Bullis. (Oreg. Sta. Bul. 197, pp. 24. July, 1923.)

Miscellaneous soil samples—Their value. R. E. Neidig and G. R. McDole. (Idaho Sta. Circ. 33, pp. 4. Jan., 1924.)

Biochemical oxidation of sulfur and its significance to agriculture. J. S. Joffe. (N. J. Stas. Bul. 374, pp. 91, figs. 4. Dec., 1922.)

Simplified apparatus and technique for the electrometric determination of hydrogen ion concentration in milk and other biological liquids. F. E. Rice and A. J. Rider. (N. Y. Cornell Sta. Mem. 16, pp. 66, fig. 1. Apr., 1923.)

Vinegar fermentation and home production of cider vinegar. A. R. Lamb and E. Wilson. (Iowa Sta. Bul. 218, pp. 14. Aug., 1923.)

Fruit jellies.—II, The role of sugar. L. W. Tarr and G. L. Baker. Del. Sta. Bul. 136, pp. 29. Mar., 1924.)

Application of the principles of jelly making to Hawaiian fruits. J. C. Ripperton. (Hawaii Sta. Bul. 47, pp. 24, pl. 1. June, 1923.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander and H. H. Shepard. (Mass. Sta. Met. Buls. 414–425, pp. 4 each. June, 1923—May, 1924.)

SOILS

Liming Wisconsin soils. A. R. Whitson, G. Richards, and H. W. Ullsperger. (Wis. Sta. Bul. 361, pp. 24, figs. 13. Feb., 1924.)

Experiments on the reclamation of alkali soils by leaching with water and gypsum. P. L. Hibbard. (Calif. Sta. Tech. Paper 9, pp. 14, Aug., 1923.)

Controlling soil moisture for vegetable crops in Missouri. J. T. Rosa. (Mo. Sta. Bul. 204, pp. 8, figs. 3. June, 1923.)

The seasonal variation of the soil moisture in a walnut grove in relation to the hygroscopic coefficient. L. D. Batchelor and H. S. Reed. (Calif. Sta. Tech. Paper 10, pp. 31, figs. 7. Sept., 1923.)

The soils of Arkansas. N. Nelson, W. H. Sachs, and R. H. Austin. (Ark. Sta. Bul. 187, pp. 83, pl. 1, figs. 24. June, 1923.)

The Iowa system of soil management. W. H. Stevenson and P. E. Brown. (Iowa Sta. Bul. 213, pp. 289–318, figs. 13. May, 1923.)

Management of the light colored clay and silt loam soils. A. T. Wiancko. (Ind. Sta. Circ. 115, pp. 20, figs. 5. Jan., 1924.)

Soil experiments on the gravelly Ozark upland. M. F. Miller and F. L. Duley. (Mo. Sta. Bul. 202, pp. 22, figs. 13. Mar., 1923.)

Soil experiments on the brown silt loam of the Ozark border region. M. F. Miller and F. L. Duley. (Mo. Sta. Bul. 203, pp. 24, figs. 7. Apr., 1923.)

A peculiar soil condition in the San Luis Valley. W. P. Headden. (Colo. Sta. Bul. 286, pp. 15, figs. 3. May, 1923.)

Sandy soils of southern peninsula of Michigan. M. M. McCool and J. O. Veatch. (Mich. Sta. Spec. Bul. 128, pp. 31, figs. 17. Jan., 1924.)

Livingston County soils. J. G. Mosier, S. V. Holt, F. A. Fisher, E. E. DeTurk, and H. J. Snider. (Ill. Sta. Soil Rpt. 25, pp. 55, pls., 4, figs. 3. June, 1923.)

Grundy County soils. R. S. Smith, E. E. DeTurk, F. C. Bauer, and L. H. Smith. (Ill. Sta. Soil Rpt. 26, pp. 66, pls. 2, figs. 6. Mar., 1924.)

Soil survey of Iowa.—Marshall County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 25, pp. 64, pl. 1, figs. 14. July, 1922.)

Soil survey of Iowa.—Madison County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 26, pp. 56, pl. 1, figs. 11. June, 1922.)

Soil survey of Iowa.—Adair County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 27, pp. 62, pl. 1, figs. 18. July, 1922.)

Soil survey of Iowa.—Cedar County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 28, pp. 63, pl. 1, figs. 14. June, 1922.)

Soil survey of Iowa.—Mahaska County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 29, pp. 72, pl. 1, figs. 13. Mar., 1923.)

Soil survey of Iowa.—Fayette County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 30, pp. 70, pls. 2, figs. 13. Mar., 1923.)

Soil survey of Iowa.—Wright County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 31, pp. 64, pl. 1, figs. 11. June, 1923.)

Soil survey of Iowa.—Johnson County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 32, pp. 72, pls. 2, figs. 14. June, 1923.)

Soils of Sheridan County.—Preliminary report. L. F. Gieseker. (Mont. Sta. Bul. 158, pp. 20, pls. 4. Apr., 1923.)

The influence of nitrogen in soil on azofication. J. E. Greaves and D. H. Nelson. (Utah Sta. Bul. 185, pp. 23. July, 1923.)

Nitrification and acidity in the muck soils of North Carolina. L. G. Willis. (N. C. Sta. Tech. Bul. 24, pp. 14. Nov., 1923.)

"Active" aluminum as a factor detrimental to crop production in many acid soils. P. S. Burgess and F. R. Pember. (R. I. Sta. Bul. 194, pp. 40, figs. 6. June, 1923.)

Erosion and surface runoff under different soil conditions. F. L. Duley and M. F. Miller. (Mo. Sta. Research Bul. 63, pp. 50, figs. 22. Dec., 1923.)

Controlling surface erosion of farm lands. F. L. Duley. (Mo. Sta. Bul. 211, pp. 23, figs. 17. Apr., 1924.)

A study of alkali and plant food under irrigation and drainage. C. W. Botkin. (N. Mex. Sta. Bul. 136, pp. 44, figs. 11. Apr., 1923.)

Some physical and chemical properties of several soil profiles. L. C. Wheeting. (Mich. Sta. Tech. Bul. 62, pp. 31, figs. 6. Jan., 1924.)

Chemical analyses of Montana soils. E. Burke and R. M. Pinckney. (Mont. Sta. Bul. 159, pp. 13. Aug., 1923.)

The chemical nature of a colloidal clay. R. Bradfield. (Mo. Sta. Research Bul. 60, pp. 60, figs. 7. June, 1923.)

FERTILIZERS

Standard fertilizer formulas and their use. G. S. Fraps. (Tex. Sta. Circ. 31, pp. 7. Sept., 1923.)

Fertilizers for Delaware crops and soils. C. A. McCue and G. L. Schuster. (Del. Sta. Circ. 12, pp. 12, figs. 11. July, 1923.)

Testing fertilizers for Missouri farmers, 1923. L. D. Haigh. (Mo. Sta. Bul. 209, pp. 55, figs. 2. Feb., 1924.)

The comparative crop effect of fertilizer chemicals, cow manure with straw bedding or with planer-shavings bedding, and of the latter supplemented with phosphorus or potassium. B. L. Hartwell, S. C. Damon, and F. K. Crandall. (R. I. Sta. Bul. 196, pp. 11. Nov., 1923.)

"Amo-phos:" Its effects upon seed germination and plant growth. D. G. Coe. (N. J. Stas. Bul. 375, pp. 102, figs. 32. Jan., 1923.)

The effect of heat upon the availability of phosphorus in basic phosphate rock. A. G. McCall and C. P. Wilhelm. (Md. Sta. Bul. 260, pp. 101–120, figs. 3. Dec., 1923.)

Marls for liming soils. S. C. Jones. (Ky. Sta. Circ. 32, pp. 12, figs. 3. Apr., 1924.)

Sulfur in relation to soil fertility. W. L. Powers. (Oreg. Sta. Bul. 199, pp. 45, figs. 17. Dec., 1923.)

BOTANY AND PLANT NUTRITION

Some mutual effects on soil and plant induced by added solutes. J. S. Burd and J. C. Martin. (Calif. Sta. Tech. Paper 13, pp. 27, figs. 3. Dec., 1923.)

Effect of salts on the intake of inorganic elements and on the buffer system of the plant. D. R. Hoagland and J. C. Martin. (Calif. Sta. Tech. Paper 8, pp. 26, figs. 5. July, 1923.)

The effect of the plant on the reaction of the culture solution. D. R. Hoagland. (Calif. Sta. Tech. Paper 12, pp. 16. Nov., 1923.)

Relationships between hydrogen ion, hydroxyl ion, and salt concentrations, and the growth of seven soil molds. H. W. Johnson. (Iowa Sta. Research Bul. 76, pp. 307–344, figs. 8. Jan., 1923.)

Is there normally a cross transfer of foods, water, and mineral nutrients in woody plants? E. C. Auchter. (Md. Sta. Bul. 257, pp. 31–62. Sept., 1923.)

Catalese activity in dormant apple twigs.—Its relation to the condition of the tissue, respiration, and other factors. A. J. Heinicke. (N. Y. Cornell Sta. Mem. 74, pp. 33, fig. 1. Mar., 1924.)

The morphology of the double kernel in *Zea mays* var. *polysperma*. Mildred E. Stratton. (N. Y. Cornell Sta. Mem. 69, pp. 18, figs. 8. June, 1923.)

The parasitism of *Colletotrichum lindemuthianum*. J. G. Leach. (Minn. Sta. Tech. Bul. 14, pp. 41, pls. 8, figs. 6. Mar., 1923.)

Studies on the parasitism of *Helminthosporium sativum*. J. J. Christensen. (Minn. Sta. Tech. Bul. 11, pp. 42, pls. 10, figs. 2. Nov., 1922.)

Major plant communities of North Carolina. B. W. Wells. (N. C. Sta. Tech. Bul. 25, pp. 20, figs. 15. Apr., 1924.)

BACTERIOLOGY

Methods of gram staining. G. J. Hucker and H. J. Conn. (N. Y. State Sta. Tech. Bul. 93, pp. 37. Mar., 1923.)

Studies on *Streptococcus paracitrovorus* group. B. W. Hammer and M. P. Baker. (Iowa Sta. Research Bul. 81, pp. 17–36. July, 1923.)

Factors influencing the activity of spore-forming bacteria in soil. J. S. Joffe and H. J. Conn. (N. Y. State Sta. Tech. Bul. 97, pp. 21. Oct., 1923.)

Flat sours.—Part I, An interesting thermophile encountered in canned string beans. Z. N. Wyant. Part II, Bacteriological studies of flat sours of cold packed canned peas. Z. N. Wyant and R. L. Tweed. (Mich. Sta. Tech. Bul. 59, pp. 29. Feb., 1923.)

Bacterial decomposition of olives during pickling. W. V. Cruess and E. H. Guthier. (Calif. Sta. Bul. 368, pp. 15, figs. 5. July, 1923.)

GENETICS

Hybridization of *Vitis rotundifolia*.—Inheritance of anatomical stem characters. C. F. Williams. (N. C. Sta. Tech. Bul. 23, pp. 31, pls. 2, figs. 16. June, 1923.)

The inheritance of blotch leaf in maize. R. A. Emerson. (N. Y. Cornell Sta. Mem. 70, pp. 16, pls. 3. June, 1923.)

The inheritance of a lethal pale green seedling character in maize. A. M. Brunson. (N. Y. Cornell Sta. Mem. 72, pp. 22, pl. 1. Jan., 1924.)

Inheritance of size and conformation in sheep. E. G. Ritzman. (N. H. Sta. Tech. Bul. 25, pp. 36, figs. 4. June, 1923.)

FIELD CROPS

Alfalfa. G. R. Quesenberry. (N. Mex. Sta. Bul. 139, pp. 19, figs. 7. May, 1923.)

Alfalfa in Connecticut. D. A. Brown and W. L. Slate, jr. (Conn. Storrs Sta. Bul. 115, pp. 299–323. June, 1923.)

Growing alfalfa in Montana. E. N. Bressman. (Mont. Sta. Circ. 116, pp. 30, figs. 22. Aug., 1923.)

Alfalfa fertilizer experiments. C. E. Craig and W. T. Conway. (N. Mex. Sta. Bul. 137, pp. 22, pl. 1, fig. 1. Mar., 1923.)

Washington barleys. E. G. Schafer, E. F. Gaines, and O. E. Barbee. (Wash. Col. Sta. Bul. 181, pp. 25, figs. 6. Feb., 1924.)
Growing field beans in Montana. C. McKee. (Mont. Sta. Circ. 125, pp. 8. Apr., 1924.)
The clovers and clover seed production in Michigan. J. F. Cox and C. R. Megee. (Mich. Sta. Spec. Bul. 130, pp. 23, figs. 14. Mar., 1924.)
Clover seed from southern Europe fails on Indiana farms. G. I. Christie. (Ind. Sta. Circ. 114, pp. 4, figs. 2. Dec., 1923.)
Growing and using sweet clover in Montana. C. McKee. (Mont. Sta. Circ. 118, pp. 32, figs. 16. Oct., 1923.)
Tifton bur clover. W. J. Davis. (Ga. Coastal Plain Sta. [Tifton, Ga.] Circ. 2, pp. 4, fig. 1. July, 1923.)
Melilotus indica on fall plant sugar cane. W. G. Taggart. (La. Stas. Bul. 189, pp. 11. Aug., 1923.)
Corn breeding. C. W. Lindstrom. (Wis. Sta. Bul. 356, pp. 38 + [1], figs. 10. Aug., 1923.)
Effect of first generation hybrids upon yield of corn. L. R. Waldron. (N. Dak. Sta. Bul. 177, pp. 16, figs. 2. Apr., 1924.)
Varieties of corn for South Dakota. A. N. Hume. (S. Dak. Sta. Bul. 204, pp. 599–611, figs. 8. Aug., 1923.)
Field corn and silage corn for silage. C. C. Hayden and A. E. Perkins. (Ohio Sta. Bul. 369, pp. 259–288. June, 1923.)
Losses and exchanges of material during the storage of corn as silage. A. E. Perkins. (Ohio Sta. Bul. 370, pp. 289–306. June, 1923.)
Ensiling versus drying soft ear corn. J. M. Evvard, A. R. Lamb, and E. J. Maynard. (Iowa Sta. Bul. 216, pp. 401–432, figs. 4. July, 1923.)
Relative water requirement of corn and sorghums. E. C. Miller. (Kans. Sta. Tech. Bul. 12, pp. 34, figs. 5. Oct., 1923.)
The relation of moisture content and certain other factors to the popping of popcorn. F. C. Stewart. (N. Y. State Sta. Bul. 505, pp. 70, pls. 4. Dec., 1923.)
The popping of popcorn. J. D. Luckett. (N. Y. State Sta. Bul. 505, pop. ed., pp. 13, figs. 3. Feb., 1924.)
Popcorn pointers. A. F. Yeager. (N. Dak. Sta. Circ. 24, pp. 8, figs. 3. Apr., 1924.)
Cotton. J. C. Overpeck and W. T. Conway. (N. Mex. Sta. Bul. 141, pp. 17, figs. 3. Jan., 1924.)
Cotton production, factors affecting earliness and yield. C. P. Blackwell and T. S. Buie. (S. C. Sta. Bul. 219, pp. 48, figs. 9. Mar., 1924.)
Cotton experiments, 1923.—Varieties, fertilizers, and weevil control. J. F. O'Kelly and R. Cowart. (Miss. Sta. Bul. 219, pp. 11. Dec., 1923.)
Cotton growing in Illinois. J. A. Evans, J. C. Hackleman, and F. C. Bauer. (Ill. Sta. Circ. 279, pp. 8, figs. 2. Mar., 1924.)
Cotton culture in Tennessee. C. A. Mooers and S. A. Robert. (Tenn. Sta. Bul. 127, pp. 19, figs. 6. Apr., 1923.)
Flaxseed production. T. E. Stoa and A. C. Dillman. (N. Dak. Sta. Bul. 178, pp. 43, figs. 11. Apr., 1924.)
Better flaxseed production. T. E. Stoa. (N. Dak. Sta. Circ. 23, pp. 8, figs. 8. Feb., 1924.)
Emergency hay crops. G. B. Mortimer. (Wis. Sta. Bul. 359, pp. 16, figs. 5. Jan., 1924.)
Studies of various factors influencing the yield and the duration of life of meadow and pasture plants. R. S. Wiggans. (N. Y. Cornell Sta. Bul. 424, pp. 24, figs. 6. Aug., 1923.)
West Virginia pastures. C. E. Stockdale. (W. Va. Sta. Circ. 35, pp. 4. Jan., 1924.)
Washington oats. E. G. Schafer, E. F. Gaines, and O. E. Barbee. (Wash. Col. Sta. Bul. 179, pp. 29, figs. 12. Dec., 1923.)
Seed potato investigations. H. O. Werner and R. F. Howard. (Nebr. Sta. Research Bul. 24, pp. 58, figs. 23. Dec., 1923.)
Certified seed in Irish potato production. A. M. Musser and C. A. Ludwig. (S. C. Sta. Bul. 218, pp. 16. Dec., 1923.)
Studies on certified seed potatoes. B. A. of the potato. W. P. Headden. (Colo. Storrs Sta. Bul. 114, pp. 285–296. May, 1923.)
The effects of nitrates on the composition of the potato. W. P. Headden. (Colo. Sta. Bul. 291, pp. 32. Apr., 1924.)
Ten years of potato spraying in New Jersey. W. H. Martin. (N. J. Stas. Bul. 383, pp. 32. Apr., 1923.)
Irrigation experiments with potatoes. F. S. Harris and D. W. Pittman. (Utah Sta. Bul. 187, pp. 15, figs. 6. Sept., 1923.)
The sorghums in Arizona. G. E. Thompson. (Ariz. Sta. Bul. 98, pp. 41–66, figs. 8. Dec., 1923.)
Soy beans: Their culture and uses. C. F. Noll and R. D. Lewis. (Pa. Sta. Bul. 187, pp. 15, fig. 1. Apr., 1924.)
Soy bean culture. T. K. Wolfe, (Va. Sta. Bul. 235, pp. 32, figs. 15. Mar., 1924.)
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Kansas State Live Stock Registry Board. (Kans. Sta. Insp. Circ. 13, pp. 119, figs. 3. Dec., 1920.)
Stallion enrollment.—XII, Report of stallion enrollment work for the year 1923, with lists of stallions and jacks enrolled. (Ind. Sta. Circ. 116, pp. 55. Dec., 1923.)
Stallion registration work in Kansas. (Kans. Sta. Insp. Circ. 20, pp. 3. Dec., 1922.)
Ninth annual report of the dairy department creamery license division for the year ending March 31, 1923. R. L. Hammond. (Ind. Sta. Circ. 111, pp. 19, figs. 2. June, 1923.)
Creamery inspection in New Jersey. Fourth annual report for the year ending June 30, 1923. F. C. Button. (N. J. Stas. Circ. 157, pp. 16, figs. 2. Sept., 1923.)

PUBLICATION LISTS AND MISCELLANEOUS

Publications available for free distribution. (Idaho Sta. Circ. 36, pp. 4. Jan., 1924.)
Author index of the publications of the Pennsylvania Agricultural Experiment Station. W. Frear and T. I. Mairs. (Pa. Sta. Bul. 180, pp. 56. Aug., 1923.)
Guide to station buildings and fields. (N. Y. State Sta. Circ. 68, pp. 4, figs. 3. [1923.].)
The use of explosives in agriculture. E. R. Cross. (N. J. Stas. Circ. 159, pp. 8, figs. 13. Nov., 1923.)
Comparison of woods for butter boxes. G. D. Turnbow. (Calif. Sta. Bul. 369, pp. 10, figs. 5. Aug., 1923.)
Sewing grain sacks. J. Koeber. (Calif. Sta. Circ. 261, pp. 11, figs. 15. Apr., 1923.)

STATISTICS OF THE STATIONS

By J. I. Schulte

For the fiscal year ended June 30, 1924, the total income from all sources reported by the experiment stations was $10,239,074.56, this amount including $1,440,000 Federal funds under the Hatch and Adams Acts and $205,000 appropriated by the Federal Government for the experiment stations in Alaska and the insular possessions. The support received by the stations from within the States included $6,115,027.20 derived from State appropriations or apportionments, $420,071.78 from fees, $1,318,839.89 from the sale of farm and other products, $164,395.42 from miscellaneous sources, and $575,740.27 carried over as balances from the previous year.

The value of additions to the equipment of the stations during the year was reported as follows:

Buildings	$1,381,638.48
Library	43,548.77
Apparatus	133,029.31
Farm implements	$171,955.27
Livestock	161,514.53
Miscellaneous	122,099.62
Total	2,013,785.98

In the work of administration and inquiry the experiment stations employed 2,385 persons. Of these 1,158 were also members of the teaching staffs of the colleges and 566 assisted in the various lines of extension work. During the year the stations issued 836 publications, including annual reports, bulletins, circulars, and press bulletins aggregating 24,602 pages. These were distributed to 930,364 addresses on regular mailing lists in addition to the number sent in response to special requests.

The statistics of the stations by States are given in the tables following:

General statistics, 1924

Station	Location	Director	Date of original organization	Date of organization under Hatch Act	Number on staff	Number of teachers on staff	Number of persons on staff who assist in extension work	Publications during fiscal year 1923–24: Number	Publications during fiscal year 1923–24: Pages	Number of names on mailing list
Alabama (College)	Auburn	M. J. Funchess	Feb. —, 1883	Feb. 24, 1888	28	13	3	10	152	1,935
Alabama (Canebrake)	Uniontown	W. A. Cammack	Jan. 1, 1886	Apr. 1, 1888	1					
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		5					
Alaska	Sitka	C. C. Georgeson			8			4	67	3,000
Arizona	Tucson	J. J. Thornber		— —, 1889	21	20	4	9	223	6,600
Arkansas	Fayetteville	Dan T. Gray		— —, 1887	28	21		8	235	12,620
California	Berkeley	E. D. Merrill	— —, 1875	Mar. —, 1888	151	108	88	42	1,858	42,538
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	44	23	15	9	248	900
Connecticut (State)	New Haven	W. L. Slate, jr	Oct. 1, 1875	May 18, 1887	32	1		10	544	9,912
Connecticut (Storrs)	Storrs	do		May 18, 1887	14	8		10	414	9,000
Delaware	Newark	C. A. McCue		Feb. 21, 1888	14	9	5	4	134	7,380
Florida	Gainesville	Wilmon Newell		— —, 1888	21	1	10	13	240	18,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	9			23	135	6,000
Guam	Guam	C. W. Edwards			4					
Hawaii	Honolulu	J. M. Westgate			6	2	5	2	40	1,172
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	36	16	6	11	60	14,506
Illinois	Urbana	H. W. Mumford		Mar. 21, 1888	101	73	30	25	618	23,000
Indiana	Lafayette	G. I. Christie	— —, 1885	Jan. —, 1888	78	19		37	670	35,870
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	86	25		37	1,219	40,250
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	80	42		14	399	12,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	59	24	7	13	667	10,000
Louisiana (Sugar)	New Orleans	W. R. Dodson	Sept. —, 1885							
Louisiana (State)	Baton Rouge	do	Apr. —, 1886		21	3	7	4	108	7,000
Louisiana (North)	Calhoun	do	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	14			11	417	20,000
Maryland	College Park	H. J. Patterson	— —, 1888	Apr. —, 1888	37	21	1	13	318	32,700
Massachusetts	Amherst	S. B. Haskell	— —, 1882	Mar. 2, 1888	51	19		23	212	16,000
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	80	27	6	33	1,518	41,978
Minnesota	University Farm, St. Paul.	W. C. Coffey	Mar. 7, 1885	— —, 1888	124	81	67	18	1,013	12,500
Mississippi	Agricultural College	J. E. Ricks		Jan. 27, 1888	34	11	1	19	170	18,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	67	58		35	865	6,267
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		4					
Montana	Bozeman	F. B. Linfield		July 1, 1893	34	16	6	23	410	6,000
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	40	16		14	539	9,181
Nevada	Reno	S. B. Doten		Dec. —, 1887	9	2		1	16	8,000
New Hampshire	Durham	J. C. Kendall	— —, 1886	Aug. 4, 1887	26	19	19	7	194	8,300
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		65	31	28	87	2,434	15,700
New Jersey (college)	do	do		Apr. 26, 1888	14					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	18	13	2	21	333	9,000
New York (State)	Geneva	R. W. Thatcher	Mar. —, 1882		50			35	969	18,000
New York (Cornell)	Ithaca	do	—— —, 1879	Apr. —, 1888	87	65	32	15	905	59,547
North Carolina	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	45	9	45	7	276	12,620
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	51	12	22	16	482	8,600
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	72			33	1,526	70,490
Oklahoma	Stillwater	C. F. Dowell		Dec. 25, 1890	27	21		3	28	17,000
Oregon	Corvallis	J. T. Jardine		July —, 1888	55	30		15	347	1,550
Pennsylvania	State College	R. L. Watts		June 30, 1887	87	87	50	9	224	44.840
Pennsylvania (Nutrition)	do	E. B. Forbes	—— —, 1907		8					
Porto Rico	Mayaguez	D. W. May			9					
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	11	3		4	76	2,700
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	32	8	8	6	272	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	17	17		8	152	16,000
Tennessee	Knoxville	C. A. Mooers	June 8, 1882	Aug. 4, 1887	23	2		11	242	12,500
Texas	College Station	B. Youngblood		Apr. 3, 1889	67	9		16	635	71,743
Utah	Logan	William Peterson		—— —, 1890	36	26	22	9	299	6,832
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	14	10	3	5	106	6,150
Virginia	Blacksburg	A. W. Drinkard, jr	—— —, 1888	—— —, 1891	31	8	3	10	242	12,000
Virgin Islands	St. Croix	J. B. Thompson			3			1	18	515
Washington	Pullman	E. C. Johnson		—— —, 1891	41	14		10	268	12.533
West Virginia	Morgantown	H. G. Knight		June 11, 1888	37	24	2	6	132	22,458
Wisconsin	Madison	H. L. Russell	—— —, 1883	—— —, 1887	96	78	62	22	729	56,877
Wyoming	Laramie	J. A. Hill		Mar. 1, 1891	22	13	7	5	204	7,100
Total					2,385	1,158	566	836	24,602	930,364

Revenues and additions to equipment, 1924

	Federal								Additions to equipment						
	Hatch	Adams	State	Balances[1] from previous year	Fees	Sales	Miscellaneous	Total	Buildings	Library	Apparatus	Farm implements	Live-stock	Miscellaneous	Total
Alabama	$15,000.00	$15,000.00	$34,500.00	$6,054.58		$16,696.57		$87,251.15	$232.53	$482.59	$1,702.81	$1,498.49	$667.05	$1,115.75	$5,699.22
Alaska[2]							$70,000.00	70,000.00	3,806.72			749.98	75.00	464.49	5,096.19
Arizona	15,000.00	15,000.00	93,305.06	1,287.88		1,613.54		126,206.48	2,728.11	205.50	479.48	1,890.59		1,444.87	6,748.55
Arkansas	15,000.00	15,000.00	50,703.37			15,676.94		96,380.31		950.00	3,249.73	3,501.41	159.96	956.99	8,818.09
California	15,000.00	15,000.00	434,539.92	26,336.43	$9,223.11	102,622.81	16,662.87	619,385.14	44,638.63	4,112.58	5,311.87	9,993.99	1,360.85	3,147.70	68,565.62
Colorado	15,000.00	15,000.00	117,540.92	28,951.72		33,332.75		209,825.39	1,172.12	580.21	5,049.87	2,519.39	8,553.46	3,210.00	21,085.05
Connecticut (State)	7,500.00	7,500.00	88,858.34	226.08	11,000.00		8,048.73	123,133.15	4,802.58	785.75	175.73	4,930.77		443.19	11,138.02
Connecticut (Storrs)	7,500.00	7,500 00	33,004.50	2,098.70			15,085.24	65,188.44	800.00	500.00	1,000.00	200.00	1,000.00	500.00	4,000.00
Delaware	15,000.00	15,000.00	17,500.00	2,528.10		11,492.69		61,520.79		546.97	875.79	1,000.00	80.00	500.00	3,002.76
Florida[3]	15,000.00	15,000.00	91,000.00	20,317.18		9,377.61	8,690.26	159,385.05	12,414.01	1,867.49	2,607.92	3,469.99	914.59	3,280.72	24,554.72
Georgia	15,000.00	15,000.00	8,000.00	2,396.94		25,786.23		66,183.17	1,000.00	611.79	490.30	467.30	1,002.66		3,572.05
Guam[2]							15,000.00	15,000.00							
Hawaii[2]							50,000.00	50,000.00	103.10	270.93	234.05	296.86		69.94	974.88
Idaho	15,000.00	15,000.00	28,203.31	209.41				58,412.72		100.00	200.00	300.00	500.00		1,100.00
Illinois	15,000.00	15,000.00	368,158.87	27,141.13		61,629.50		486,929.50	319,167.19					34,265.09	353,432.28
Indiana	15,000.00	15,000.00	225,081.38	108,103.02	123,443.50	76,312.16	21,072.72	584,012.78	44,043.16	1,506.33	2,224.28	7,312.98	14,157.54	1,356.53	70,600.82
Iowa	15,000.00	15,000.00	250,000.00	32,569.13		36,531.95		349,101.08	225.00		1,945.61	1,731.73	418.00		4,320.34
Kansas	15,000.00	15,000.00	103,550.00	12,527.60		55,921.03		201,998.63	10,507.13	327.31	348.26	9,951.17	5,530.00	930.16	27,594.03
Kentucky	15,000.00	15,000.00	68,000.00	45,243.79	99,158.43	41,144.40	5,000.00	288,546.62		1,019.33	365.90	405.50	2,949.20	453.31	5,193.24
Louisiana	15,000.00	15,000.00	40,000.00	3,975.87	34,157.23	7,264.00	6,193.42	121,590.52	2,125.86	672.46	1,153.99	2,524.23	1,547.38	517.86	8,541.78
Maine	15,000.00	15,000.00	25,000.00		11,886.07	15,420.18		82,306.25	1,366.42	705.81	456.74	2,872.33	68.00	1,670.16	7,139.46
Maryland	15,000.00	15,000.00	86,943.72			16,837.37	11,409.25	145,190.34	5,848.05	307.18	3,891.40	1,693.86	1,432.00	4,820.19	17,992.68
Massachusetts	15,000.00	15,000.00	124,359.87		40,733.93	9,710.88	393.54	205,198.22	7,571.10	1,163.99	633.40	2,264.09		767.36	12,399.94
Michigan	15,000.00	15,000.00	157,963.95			15,626.93		203,590.88	2,334.63	940.15	3,396.63	8,359.51	2,043.00	1,220.23	18,294.15
Minnesota	15,000.00	15,000.00	380,518.80			49,709.71		460,228.51	351,742.81	5,251.28	25,313.68	14,984.86	19,797.64	12,335.82	429,426.09
Mississippi	15,000.00	15,000.00	88,196.75	3,936.98		7,394.68		129,528.41	119,025.00	5,676.60	9,599.93	17,443.40	29,693.00	8,696.38	190,134.31
Missouri	15,000.00	15,000.00	67,108.55	35,322.76	28,698.16	57,618.41		218,747.88	310.30	58.77	3,044.59	247.23	2,274.04	3,646.19	9,581.12
Montana	15,000.00	15,000.00	107,598.62			27,479.06		165,077.68	2,500.00	150.00	700.00	3,500.00	800.00	750.00	8,400.00
Nebraska	15,000.00	15,000.00	123,301.00	22,759.10		40,899.12		216,959.22		271.48	4,139.76	5,263.30	16,105.72		25,780.26
Nevada	15,000.00	15,000.00	783.65	861.32		2,195.93		33,840.90	82.71	243.30	298.86	24.80	606.90	1,144.70	2,401.27
New Hampshire	15,000.00	15,000.00	7,000.00	986.70		2,081.70	14,724.91	54,793.31		425.49	1,453.15	30.00		433.55	2,342.19
New Jersey (College)	15,000.00	15,000.00						30,000.00	110,198.19	309.43	4,004.07	1,166.00	1,183.00	3,776.45	120,637.14
New Jersey (State)			167,500.00		52,029.42	24,324.12		243,853.54							
New Mexico	15,000.00	15,000.00	7,500.00	22,208.64		10,453.70		70,162.34	945.63	7.50	259.30	1,614.06	153.00	2,750.00	5,729.49
New York (Cornell)	13,500.00	13,500.00	239,130.65			34,398.47	266.38	300,795.50	12,720.40	1,218.36	10,558.97	3,038.93	196.01	1,757.16	29,489.83

New York (State)	1,500.00	1,500.00	247,451.12	-----	-----	3,312.17	-----	253,763.29	3,280.00	825.00	3,800.00	1,200.00	-----	1,700.00	10,805.00
North Carolina	15,000.00	15,000.00	149,161.99	1,497.17	-----	46,030.67	-----	226,689.83	13,255.29	567.24	1,448.57	3,623.25	2,437.95	3,156.86	24,489.16
North Dakota	15,000.00	15,000.00	296,516.68	40,469.85	-----	65,995.02	9,508.42	442,489.97	6,000.00	250.00	1,000.00	800.00	2,500.00	6,350.00	16,900.00
Ohio	15,000.00	15,000.00	597,575.00	13,301.73	-----	55,875.23	673.30	697,425.26	27,433.41	439.27	3,135.33	9,226.74	9,507.30	-----	49,742.05
Oklahoma [4]	15,000.00	15,000.00	12,500.00	-----	-----	6,679.26	-----	49,179.26	60,000.00	140.88	1,318.32	1,554.00	7,500.00	2,874.21	73,387.41
Oregon	15,000.00	15,000.00	99,500.00	55,337.22	-----	-----	32,161.82	216,999.04	3,844.30	473.23	1,324.72	1,656.71	6,339.09	5,000.00	18,638.05
Pennsylvania	15,000.00	15,000.00	62,225.12	-----	-----	18,636.43	-----	110,861.55	-----	815.10	4,306.12	2,208.74	4,214.02	-----	11,543.98
Porto Rico [2]	-----	-----	-----	-----	-----	-----	50,000.00	50,000.00	-----	-----	-----	-----	-----	-----	-----
Rhode Island	15,000.00	15,000.00	3,087.27	2,885.14	-----	7,578.88	-----	43,551.29	56.37	345.35	8.00	65.07	75.00	182.62	732.41
South Carolina	15,000.00	15,000.00	70,777.60	1,928.71	-----	35,989.24	-----	138,695.55	358.00	661.32	239.45	2,548.14	400.00	1,068.68	5,275.59
South Dakota	15,000.00	15,000.00	35,420.00	5,547.02	-----	9,345.00	3,132.18	83,444.20	-----	-----	1,050.00	400.00	-----	-----	1,450.00
Tennessee	15,000.00	15,000.00	41,949.52	-----	-----	13,633.69	-----	85,583.21	-----	473.36	135.45	2,710.53	-----	304.90	3,624.24
Texas	15,000.00	15,000.00	294,000.00	12,823.23	-----	78,124.43	-----	414,947.66	75,520.72	292.71	4,730.42	13,479.76	4,015.58	254.80	98,293.99
Utah	15,000.00	15,000.00	46,904.73	562.83	-----	9,322.41	1,000.00	87,789.97	1,600.00	600.00	400.00	400.00	300.00	100.00	3,400.00
Vermont	15,000.00	15,000.00	5,000.00	586.97	9,741.93	517.80	-----	45,846.70	1,841.06	187.19	2,479.44	262.12	740.50	-----	5,510.31
Virginia	15,000.00	15,000.00	64,912.50	11,362.68	-----	8,732.08	631.53	115,638.79	2,971.28	656.53	844.45	2,526.45	500.00	-----	7,498.71
Virgin Islands [2]	-----	-----	-----	-----	-----	-----	20,000.00	20,000.00	2,133.31	29.95	-----	291.17	126.56	-----	2,580.99
Washington	15,000.00	15,000 00	107,030.78	17,268.72	-----	51,987.20	-----	206,286.70	7,403.03	470.65	509.51	2,397.22	1,190.55	579.00	12,549.96
West Virginia	15,000.00	15,000.00	90,000.00	4,451.46	-----	27,254.55	-----	151,706.01	75,000.00	608.98	2,681.15	6,950.00	2,302.00	1,000.00	88,542.13
Wisconsin	15,000.00	15,000.00	243,663.66	-----	-----	67,944.30	9,740.85	351,348.81	27,000.00	2,581.99	5,545.36	3,932.87	3,709.48	3,103.76	45,873.46
Wyoming	15,000.00	15,000.00	12,500.00	1,674.48	-----	2,329.09	-----	46,503.57	11,530.33	1,861.44	2,906.95	475.75	2,388.50	-----	19,162.97
Total	720,000.00	720,000.00	6,115,027.20	575,740.27	420,071.78	1,318,839.89	369,395.42	10,239,074.56	1,381,638.48	43,548.77	133,029.31	171,955.27	161,514.53	122,099.62	2,013,785.98

[1] Not including balances from Federal funds.
[2] Supported by direct appropriations to the United States Department of Agriculture.
[3] Including a balance of 1 cent on the Hatch fund.
[4] Balances on Federal funds refunded to the Treasury. See pp. 111, 113.

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$9,484.08	$1,940.70	$508.79	$473.04	$66.79		$238.11
Arizona	15,000.00	14,048.95	146.40		53.00			3.75
Arkansas	15,000.00	8,280.00	1,906.57	1,512.98	352.21	157.78	$111.33	115.94
California	15,000.00	15,000.00						
Colorado	15,000.00	13,894.25	102.64	2.32	49.76			140.99
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	9,716.56	780.81	1,848.04	643.39	18.10	92.65	584.20
Florida [1]	15,000.00	15,000.00						
Georgia	15,000.00	9,042.33	3,054.15	289.00	459.80	375.98	609.95	36.18
Idaho	15,000.00	11,398.24	1,514.66		61.75	7.21	51.03	244.05
Illinois	15,000.00	15,000.00						
Indiana	15,000.00	14,846.23	149.76		.74			
Iowa	15,000.00	8,415.00	864.12	1,337.10	134.20	54.33	39.69	12.59
Kansas	15,000.00	9,700.00	4,427.22	6.28	99.31			255.61
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	6,873.32	3,744.41	315.00	262.62	96.87	466.56	32.00
Maine	15,000.00	7,516.07	3,649.48	271.00	357.34	143.93	765.55	95.28
Maryland	15,000.00	14,864.71	45.29					
Massachusetts	15,000.00	15,000.00						
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,744.96	3,174.18		27.40	159.47	190.13	
Missouri	15,000.00	7,218.93	3,674.83	7.35	181.01	164.23	63.84	272.70
Montana	15,000.00	14,780.00		195.93	6.07			18.00
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	10,075.17	2,306.62		249.37	47.30	84.41	
New Hampshire	15,000.00	10,590.43	430.10	699.96	404.41	278.71	600.00	252.10
New Jersey	15,000.00	11,130.82	670.28	187.36	218.66	8.20	208.19	236.21
New Mexico	15,000.00	7,483.49	2,608.28	1,723.12	132.22	94.29	205.74	136.03
New York (Cornell)	13,500.00	5,840.00	4,526.36		25.06	97.88	96.39	203.44
New York (State)	1,500.00	300.00	1,200.00					
North Carolina	15,000.00	12,415.59	1,882.00		203.64	26.31	347.86	124.60
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	6,783.34	3,151.92		181.95	340.23	1,083.00	25.85
Oklahoma	15,000.00	6,577.50	1,593.69	710.13	144.87	30.37	33.12	676.80
Oregon	15,000.00	10,270.50	2,661.32	852.14	29.19	17.88		64.16
Pennsylvaa	15,000.00	11,799.95	666.19	1,806.76	1.04	30.26		7.89
Rhode Island	15,000.00	5,627.96	4,777.76	1,080.49	144.26	452.91	319.60	.82
South Carolina	15,000.00	8,596.04	1,736.52	652.76	579.19	142.51	12.89	20.20
South Dakota	15,000.00	8,594.93	1,590.71	2,142.51	230.37	27.31		106.74
Tennessee	15,000.00	10,853.34	1,772.49	459.94	304.48	69.23	728.79	66.91
Texas	15,000.00	11,632.88	100.00		231.56			
Utah	15,000.00	10,700.00	1,677.79		42.80	139.58		56.56
Vermont	15,000.00	7,098.92	2,257.57	895.00	250.15	63.32	948.26	127.84
Virginia	15,000.00	10,607.07	3,246.52	12.58	191.61	54.22	46.38	15.53
Washington	15,000.00	10,154.82	2,185.08	1,109.26	43.26	26.83		
West Virginia	15,000.00	9,035.37	2,166.25	182.44	34.36	10.63		257.97
Wisconsin	15,000.00	10,050.00	1,868.51	633.67		6.21		959.91
Wyoming	15,000.00	6,745.00	4,529.87	291.17	1.04		49.52	292.19
Total	720,000.00	522,786.75	78,781.05	19,733.08	6,805.13	3,208.87	7,154.88	5,681.15

[1] Including unexpended balance of 1 cent.

act of March 2, 1887 (Hatch Act), for the year ended June 30, 1924

Classified expenditures—Continued

Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
$181.89	$244.03	$403.08	$305.39	$293.31	$334.09	$246.82	$1.80	$45.55	-	$232.53	-
29.15	-	124.01	201.00	-	-	-	-	393.74	-	-	-
897.01	257.10	550.77	100.18	121.70	401.74	70.92	88.00	29.27	-	46.50	-
-	-	-	-	-	-	-	-	-	-	-	-
125.37	-	44.79	8.83	6.00	21.25	387.93	-	111.04	-	104.83	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
129.10	18.00	-	268.07	102.04	47.97	236.52	-	491.13	$23.42	-	-
-	-	-	-	-	-	-	-	-	-	-	-
377.90	405.21	-	48.87	213.39	10.85	-	-	76.39	-	-	-
189.43	-	1,110.79	4.75	1.50	-	-	42.00	374.59	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
3.27	-	-	-	-	-	-	-	-	-	-	-
679.59	43.75	3,321.56	-	98.07	-	-	-	-	-	-	-
103.30	87.63	-	-	120.00	20.18	-	-	180.47	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
1,108.88	25.92	164.77	511.89	569.36	30.75	-	-	622.62	76.42	98.61	-
142.98	-	1,316.62	319.41	41.86	17.42	75.00	-	280.88	-	7.18	-
-	-	-	-	-	-	90.00	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
849.94	195.21	300.60	-	262.92	-	-	-	95.19	-	-	-
588.49	20.50	2,130.72	24.00	225.75	52.11	258.60	47.60	69.34	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
173.91	-	72.15	245.50	223.78	547.05	2.94	241.50	629.24	-	101.06	-
180.31	73.55	-	342.85	94.05	159.70	490.16	-	363.15	-	40.52	-
225.43	52.50	360.00	-	349.38	27.60	51.00	-	1,268.61	4.06	1.70	-
267.24	150.30	484.97	-	721.23	19.65	-	153.00	398.02	-	422.42	-
481.30	506.18	-	-	476.07	2.35	772.20	-	337.05	4.21	131.51	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
192.65	737.00	1,498.96	-	787.23	-	217.87	-	-	-	-	-
1,029.55	62.30	798.50	106.13	740.48	656.22	500.30	-	1,016.92	-	172.25	$[2]150.87
183.79	-	104.65	10.00	9.90	-	-	-	796.47	-	-	-
403.20	7.50	-	-	16.22	-	2.50	-	258.49	-	-	-
280.83	1,089.59	496.43	140.10	128.44	49.25	-	-	145.43	28.88	237.26	-
482.62	416.37	1,037.03	701.06	201.59	226.80	58.83	-	115.78	-	19.80	-
474.38	16.00	41.40	137.90	353.53	681.15	421.57	-	173.50	8.00	-	-
80.51	57.00	-	321.06	29.35	43.67	37.58	-	86.57	1.49	87.59	-
207.00	-	-	-	1,215.51	818.95	73.22	-	-	-	720.88	-
263.01	-	1,256.40	19.89	166.29	24.30	157.15	-	448.95	-	47.28	-
488.44	140.17	-	184.19	187.92	57.75	561.56	700.00	431.48	-	607.43	-
391.79	67.51	1.35	106.99	62.57	38.45	-	-	24.65	20.00	112.78	-
199.76	-	-	15.08	236.36	-	-	-	1,029.55	-	-	-
733.66	184.19	260.07	-	516.33	-	675.19	-	943.54	-	-	-
284.98	43.80	-	-	153.20	-	966.58	-	33.14	-	-	-
-	-	3,000.00	-	3.70	-	50.25	-	37.26	-	-	-
12,430.66	4,901.31	18,879.62	4,123.14	8,729.03	4,289.25	6,404.69	1,273.90	11,308.01	166.48	3,192.13	150.87

[2] Refunded to the Treasury.

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000.00	$11,055.51	$802.87	$71.29	$150.41	$269.56	$834.84	$145.52
Arizona	15,000.00	12,468.26	404.55	98.26	75.66		360.02	170.60
Arkansas	15,000.00	9,430.70	2,455.73	22.36	76.11	63.05	788.37	151.10
California	15,000.00	12,254.06	915.56	106.58	2.50	49.26	419.28	309.75
Colorado	15,000.00	13,994.33	51.90				142.75	22.40
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	12,117.56	539.25	26.31	33.26		772.79	458.66
Florida	15,000.00	15,000.00						
Georgia	15,000.00	11,198.52	8.00	133.27	114.19	580.90	303.74	57.63
Idaho	15,000.00	11,135.05	1,450.13	14.48	53.27	52.80	1,137.95	214.32
Illinois	15,000.00	13,259.82	1,740.18					
Indiana	15,000.00	11,789.72	519.11	71.49			609.01	226.02
Iowa	15,000.00	9,395.00	2,575.20	35.54	13.78	114.71	1,069.48	527.44
Kansas	15,000.00	10,300.00	3,417.44	29.69	8.05		223.58	98.70
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	12,150.00	805.65	1.92	32.02	264.75	608.19	99.42
Maine	15,000.00	15,000.00						
Maryland	15,000.00	13,876.49	140.00	8.79		38.02	449.80	
Massachusetts	15,000.00	15,000.00						
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	10,996.80	2,549.10	2.00	69.20	58.92	22.98	822.70
Missouri	15,000.00	5,118.83	2,614.21	51.22	296.06	398.28	1,319.34	350.91
Montana	15,000.00	10,733.62	2,447.82	5.80	47.65		215.02	225.14
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	8,154.30	2,899.08	22.32	99.45	229.54	437.79	225.98
New Hampshire	15,000.00	11,910.53	842.79	26.00	144.79		385.43	84.37
New Jersey	15,000.00	12,840.01	169.18	28.11	9.48	296.26	1,167.80	54.70
New Mexico	15,000.00	9,163.60	2,335.62	178.98	372.68	188.61	1,293.02	214.46
New York (Cornell)	13,500.00	11,086.13	1,011.52	9.19			333.20	358.63
New York (State)	1,500.00	1,500.00						
North Carolina	15,000.00	13,415.02	924.05		63.85		344.52	65.47
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	11,452.77	2,724.70	5.46			198.34	137.29
Oklahoma	15,000.00	10,280.00	800.63	30.15	44.33	11.43	752.54	535.80
Oregon	15,000.00	13,443.34	753.41	11.96	63.69	54.28	279.90	209.42
Pennsylvania	15,000.00	11,500.25	589.72	3.62	50.25	10.40	867.30	96.80
Rhode Island	15,000.00	9,634.27	2,513.98	.37	28.72	387.33	210.85	59.09
South Carolina	15,000.00	10,723.24	1,836.89	305.78	148.44	278.23	337.18	87.95
South Dakota	15,000.00	8,361.59	3,796.00	8.12	15.79		328.94	272.51
Tennessee	15,000.00	13,450.00	20.72	18.70	144.63	226.94	261.57	77.87
Texas	15,000.00	13,611.22	601.55	16.25		38.50	19.35	186.76
Utah	15,000.00	9,050.04	4,064.26	24.10	92.06		500.29	293.98
Vermont	15,000.00	8,180.18	2,776.66	95.75	46.46	66.84	242.75	190.21
Virginia	15,000.00	10,685.00	3,447.38	10.40	4.95	49.20	220.15	102.56
Washington	15,000.00	12,822.80	993.90	25.90	2.00		264.27	240.52
West Virginia	15,000.00	10,767.48	812.50				548.23	753.82
Wisconsin	15,000.00	8,850.00	3,370.95		1.82		503.49	76.51
Wyoming	15,000.00	12,830.32	580.08	7.48		40.00	303.35	72.26
Total	720,000.00	569,986.36	61,302.27	1,507.64	2,305.55	3,767.81	19,077.40	8,277.27

[1] Refunded to the Treasury.

act of March 16, 1906 (Adams Act), for the year ended June 30, 1924

Classified expenditures										
Fertilizers	Feeding stuffs	Library	Tools, implements and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
------	$655.75	$96.62	$94.52	$17.75	$640.56	$149.62	$16.18	------	------	------
$17.50	------	4.50	13.86	------	199.28	------	881.12	------	$306.39	------
235.72	300.28	3.50	128.00	1.54	890.82	42.90	353.55	------	56.27	------
------	274.89	28.55	14.70	140.31	151.64	128.22	204.70	------	------	------
------	5.97	9.91	------	358.50	270.59	------	143.65	------	------	------
------	------	------	------	------	------	------	------	------	------	------
------	------	------	------	------	------	------	------	------	------	------
27.00	------	45.42	2.10	------	639.27	------	296.38	$7.00	35.00	------
------	------	------	------	------	------	------	------	------	------	------
74.00	1,428.86	26.76	10.00	------	279.03	785.10	------	------	------	------
------	30.42	------	26.00	------	160.65	------	695.93	29.00	------	------
------	------	------	------	------	------	------	------	------	------	------
192.05	.40	42.00	178.23	1.45	384.71	797.40	188.41	------	------	------
5.25	915.59	5.25	85.19	------	103.32	------	154.25	------	------	------
------	342.74	------	37.45	53.43	6.21	239.00	115.53	------	128.18	------
------	------	------	------	------	------	------	------	------	------	------
------	133.60	62.95	39.25	49.00	719.64	------	33.61	------	------	------
------	------	------	------	------	------	------	------	------	------	------
------	------	9.70	8.00	28.09	423.61	------	------	------	17.50	------
------	------	------	------	------	------	------	------	------	------	------
------	------	------	------	------	------	------	------	------	------	------
------	------	------	------	------	------	------	------	------	------	------
9.00	------	46.63	------	------	326.62	------	96.05	------	------	------
4.70	2,160.06	6.00	204.86	136.61	1,969.05	106.65	148.87	3.90	110.45	------
------	------	25.16	66.66	36.90	702.74	50.00	443.49	------	------	------
------	------	------	------	------	------	------	------	------	------	------
------	1,542.68	2.80	168.15	------	44.72	338.00	835.19	------	------	------
------	372.14	------	209.54	9.16	638.45	------	48.31	------	328.49	------
------	------	------	30.60	20.15	200.50	------	------	------	183.21	------
73.44	------	7.50	682.26	23.80	259.30	120.00	------	------	86.73	------
------	------	------	19.97	36.50	644.86	------	------	------	------	------
------	------	------	------	------	------	------	------	------	------	------
------	------	------	------	------	110.43	------	76.66	------	------	------
------	------	------	------	------	------	------	------	------	------	------
------	179.37	------	59.60	------	242.47	------	------	------	------	------
------	724.76	------	536.89	78.85	507.52	401.60	------	------	216.20	[1] $79.30
1.00	70.77	2.47	52.57	7.00	19.00	------	17.19	------	14.00	------
40.80	72.26	190.26	40.25	9.15	1,406.88	------	105.78	2.10	14.18	------
------	1,781.99	14.66	41.32	50.00	1.90	55.50	3.30	------	216.72	------
300.00	------	108.72	208.18	19.20	646.19	------	------	------	------	------
------	60.43	1.80	461.61	318.45	1,054.16	115.00	160.06	------	45.54	------
------	------	28.62	247.92	23.65	215.95	------	258.69	1.37	23.37	------
------	69.63	------	200.37	51.20	5.00	------	30.32	------	169.85	------
------	------	14.50	20.30	40.30	457.84	------	364.31	------	78.02	------
28.50	620.89	------	33.20	18.15	1,827.78	40.50	82.13	------	750.00	------
------	110.50	------	38.35	5.25	64.05	------	125.50	------	136.71	------
12.00	------	27.21	48.80	56.60	79.70	------	426.30	------	------	------
60.00	323.54	5.00	382.00	22.85	618.38	------	706.20	------	------	------
.60	1,889.14	------	------	------	291.49	16.00	------	------	------	------
------	956.04	------	20.91	7.16	73.60	7.00	94.65	------	7.15	------
1,081.56	15,022.70	816.49	4,411.61	1,621.00	17,277.91	3,392.49	7,105.31	43.37	2,923.96	79.30

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906

State or Territory	Hatch Act		Adams Act	
	1888–1923	1924	1906–1923	1924
Alabama	$538,956.42	$15,000.00	$236,619.89	$15,000.00
Arizona	504,803.10	15,000.00	239,955.61	15,000.00
Arkansas	538,139.12	15,000.00	239,900.00	15,000.00
California	540,000.00	15,000.00	239,926.84	15,000.00
Colorado	539,718.82	15,000.00	238,638.93	15,000.00
Connecticut	540,000.00	15,000.00	240,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	538,382.87	15,000.00	235,475.12	15,000.00
Florida	539,966.05	14,999.99	239,996.06	15,000.00
Georgia	535,593.43	15,000.00	227,092.87	15,000.00
Idaho	464,324.13	15,000.00	235,842.22	15,000.00
Illinois	539,564.95	15,000.00	239,851.62	15,000.00
Indiana	539,901.19	15,000.00	240,000.00	15,000.00
Iowa	540,000.00	15,000.00	240,000.00	15,000.00
Kansas	539,995.00	15,000.00	240,000.00	15,000.00
Kentucky	539,996.57	15,000.00	240,000.00	15,000.00
Louisiana	540,000.00	15,000.00	240,000.00	15,000.00
Maine	539,999.62	15,000.00	240,000.00	15,000.00
Maryland	539,967.40	15,000.00	239,236.48	15,000.00
Massachusetts	539,617.70	15,000.00	240,000.00	15,000.00
Michigan	539,676.10	15,000.00	236,341.20	15,000.00
Minnesota	539,917.78	15,000.00	239,345.00	15,000.00
Mississippi	540,000.00	15,000.00	240,000.00	15,000.00
Missouri	535,097.24	15,000.00	239,999.90	15,000.00
Montana	450,000.00	15,000.00	237,417.04	15,000.00
Nebraska	539,932.16	15,000.00	240,000.00	15,000.00
Nevada	539,214.32	15,000.00	238,180.28	15,000.00
New Hampshire	540,000.00	15,000.00	240,000.00	15,000.00
New Jersey	539,949.97	15,000.00	239,392.06	15,000.00
New Mexico	504,509.05	15,000.00	240,000.00	15,000.00
New York	539,757.18	15,000.00	239,463.01	15,000.00
North Carolina	540,000.00	15,000.00	225,000.00	15,000.00
North Dakota	481,502.26	15,000.00	239,638.85	15,000.00
Ohio	540,000.00	15,000.00	238,514.02	15,000.00
Oklahoma	464,153.03	14,849.13	219,614.49	14,920.70
Oregon	525,156.64	15,000.00	235,000.00	15,000.00
Pennsylvania	539,967.43	15,000.00	239,995.41	15,000.00
Rhode Island	540,000.00	15,000.00	237,464.20	15,000.00
South Carolina	539,542.15	15,000.00	238,460.12	15,000.00
South Dakota	483,250.00	15,000.00	235,000.00	15,000.00
Tennessee	540,000.00	15,000.00	240,000.00	15,000.00
Texas	540,000.00	15,000.00	237,592.26	15,000.00
Utah	405,000.00	15,000.00	239,821.94	15,000.00
Vermont	540,000.00	15,000.00	240,000.00	15,000.00
Virginia	537,824.12	15,000.00	239,949.01	15,000.00
Washington	477,102.65	15,000.00	236,080.11	15,000.00
West Virginia	539,968.71	15,000.00	237,859.12	15,000.00
Wisconsin	540,000.00	15,000.00	240,000.00	15,000.00
Wyoming	525,000.00	15,000.00	240,000.00	15,000.00
Total	25,301,697.16	719,849.12	11,422,663.66	719,920.70

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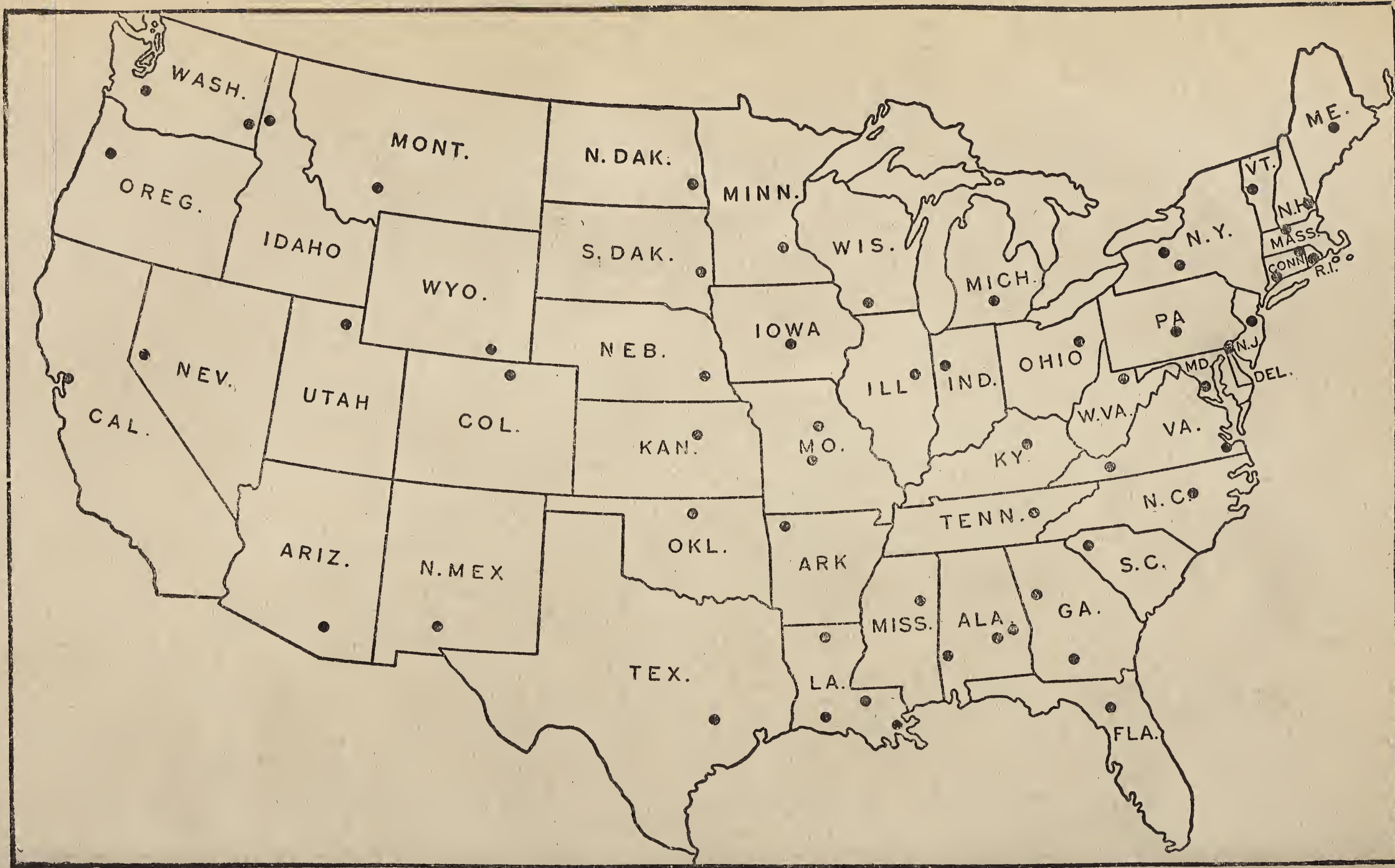

THE AGRICULTURAL EXPERIMENT STATIONS OF THE UNITED STATES